THE UNIVERSITY OF ALBERTA

# A COMPARISON OF THE EFFECTS OF SHORT INTENSIVE AND PROLONGED INTENSIVE EXERCISE PROGRAMS ON TREADMILL PERFORMANCE AND CERTAIN CARDIO-RESPIRATORY FUNCTIONS

A THESIS

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APPROVAL SHEET

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "A Comparison of the Effects of Short Intensive and Prolonged Intensive Exercise Programs on Treadmill Performance and Certain Cardio-Respiratory Functions" submitted by Leonard Allen Cooper in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

The purpose of this study was to compare two types of exercise programs of different intensities and duration (5BX and circuit training) on the basis of their contribution to cardio-respiratory fitness. Thirty male subjects were divided into 3 equated groups. Group A participated in the 5BX program, Group B in a 13 station circuit training program and Group C acted as control. Group A was further divided into sub-groups $A_1$ and $A_2$. Both subgroups participated in the first four 5BX exercises as perscribed. In order to determine whether the 2 programs were equivalent in their contribution, $A_1$ ran on the spot as specified for the fifth activity and $A_2$ ran the designated distance. The exercise programs continued 5 days a week for 5 weeks. Two treadmill performance tests of different intensities (walking and running) and a test of respiratory fitness were given each subject before, after 2.5 weeks, and upon completion of the exercise programs. Cardio-respiratory parameters investigated included heart rate, $O_2$ consumption and the ventilatory R.Q. at rest, during exercise, and during recovery. Following 5 weeks of intensive training the exercise groups exhibited increases in treadmill performance times and maximal breathing capacity; generally lower resting, exercise, and recovery heart rates and $O_2$ intake; and (with the exception

of Group A for the final exhaustion run) unchanged or higher R.Q. values. Both circuit training and 5BX contributed to gains in cardio-respiratory fitness. To derive maximum benefit from the 5BX program running distance was recommended as the fifth exercise. It was concluded that the quality and intensity of the exercise is more important than the quantity and duration.

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## CHAPTER I

## STATEMENT OF THE PROBLEM

Introduction. It has taken the impetus of war to sufficiently stress the major importance of physical fitness of the individual and to create a sustained awareness and subsequent attention to this subject (1-17). The necessity for a thorough inquiry into the nature and needs of physical fitness remains paramount. This study is concerned with some aspects of physical fitness. It recognizes a shift in emphasis in physical education, training and fitness programs to the task of attempting to fit a healthy individual into a health environment (18:399). An understanding and evaluation of the term "physical fitness" is essential but difficult. The term appears to be inadequate. Physical fitness has established meaning only in terms of the task undertaken. As a result, it has a great diversity of interpretation and wide usage both lay and medical (3:255), (19:308), (20:140). Since the demands upon the organism vary in degree according to the nature of the activity, fitness for one type of work does not imply fitness for another (19:307), (20:140). Astrand (19:307) suggests that an individual's physical fitness will ultimately be determined by his natural endowment and his state of health. It becomes apparent, then, that there is great variation in the state of fitness from individual to individual (1:836).

The effects of training upon physical fitness are also of major importance. "Training aims at increasing the possibilities for the organism to perform a special task." (19:321), (21:137). Technical training strives to improve dexterity. Endurance training aims to strengthen the organism generally, especially the circulo-respiratory system. While we may know the result of training upon different bodily functions, it is apparent little is known about the essence of training itself.

The Problem. The purpose of this study is to compare the effects of two types of fitness programs, one a short intensive program (5BX), the other a more prolonged intensive program (Circuit Training), on treadmill performance and on certain cardio-respiratory functions. The study will investigate and compare the relative effects of the two exercise programs on,

a) performance times of two treadmill tests of varying intensities;

b) resting, exercising and recovery measures associated with two types of treadmill tests concerning the

  (1) heart rate

  (2) oxygen intake and carbon dioxide production

  (3) respiratory quotient;

c) resting maximum breathing capacity.

Sub-Problem. A comparison of the effects of running on the spot in the degree specified by the 5BX program to run-

ning an equivalently designated distance will be made.

Justification of the Problem. A major objective of Physical Education is to develop, improve and maintain some degree of physical fitness. Physical education classes consist of a variety of physical activities designed to meet this aim. Because of the lack of sufficient experimental evidence, the physical educator is frequently uncertain about the actual contribution of these activities to the physical education objective. Comparative analyses of existing programs of exercise are essential in order that their relative contribution to the objectives desired can be assessed. Of particular importance in this regard is the need for evaluation of concomitant exercise programs varying in intensity and duration and conducted under similar circumstances.

Assumptions. Throughout this study it will be assumed that,

a) physical fitness is a measurable entity;

b) cardio-respiratory fitness is a component of physical fitness;

c) some aspects of cardio-respiratory fitness can be measured in terms of,

(1) heart rate. The resting heart rate has a significant validity as a test of the effect of training. Also, the slower the heart rate re-

covery following standard exercise the lower that aspect of cardiovascular fitness measured by heart rate recovery. In addition, any significant decrease in the exercise heart rate represents an increase in cardiovascular fitness.

(2) treadmill performance time. An increase in performance time on the treadmill is construed as an improvement in cardio-respiratory fitness.

(3) respiratory fitness is manifested by changes in the rate of oxygen absorption and in the bellows action of the ventilatory mechanism. Improved respiratory efficiency will result in a greater absorption of oxygen per liter of ventilation and in the ability of the respiratory apparatus to move greater quantities of air under stress.

(4) changes in the respiratory quotient (R.Q.). A significant lowering of the R.Q. is attributable to training.

d) any changes associated with the variables considered are due to the exercise programs;

e) factors that motivated the subjects to continue working were constant throughout the study;

f) each subject performed maximally at all times.

Limitations.

a) Because of the time requirements involved in ad-

ministering and evaluating the tests and the limited availability of certain facilities, a more extensive exploration of several of the variables considered was not possible.

b) Only a limited number of parameters of one aspect of physical fitness are considered.

c) The sample is restricted to thirty subjects who willingly volunteered their services for this study.

d) There is only one 5BX program. There are, however, many forms of Circuit Training. The particular type of circuit considered in this study is one currently undergoing extensive use at the University of Alberta. This is the basis for its selection. It is conceivable that other forms of circuit training could lead to different conclusions.

e) The effects of the exercise programs on the cardio-respiratory variables selected are considered over a 5 week period only. It is also conceivable that a longer training period could presumably lead to different conclusions.

Definition of Terms.

a) Physical Fitness - Physical fitness, ". . . consists in the ability of the organism to maintain the various internal equilibria as closely as possible to the resting state during strenuous

exertion and to restore promptly after exercise any equilibriums which have been disturbed." (20:141).

Physical fitness, therefore, embraces the total of body functions. It is the capacity of the individual for prolonged heavy work. (19, 22, 23, 24). Generally it denotes a, ". . . quantitative and unspecified evaluation of the individual's physical state." (19:307).

b) Cardio-Respiratory Fitness - Denotes ". . . the ability to sustain prolonged activity in which the cardio-respiratory mechanisms are the primary limiting factors." (25:348).

c) Maximal Work - Work produced by tasks requiring 15 - 20 times the basal $O_2$ consumption. (26:82). It is referred to as anaerobic work since the cardio-respiratory system is unable to supply $O_2$ at the required rate, the difference made up by the $O_2$ debt.

d) Sub-Maximal Work - Work produced by tasks when the available $O_2$ supply is sufficient to meet the needs of the working tissues.

e) Maximal Oxygen Consumption - The point at which the cardio-respiratory system can no longer in-

crease delivery of $O_2$ to the working muscles, thus the $O_2$ consumption becomes stable. At this point the body must be able to metabolize carbohydrates to release energy to the muscles and to build up an $O_2$ debt.

f) Maximum Breathing Capacity (MBC) - "The maximum volume of gas that can be breathed per minute." (27:129), (28:19), (29:46).

g) 5BX Program of Exercise - A short intensive exercise program devised by the RCAF in 1957. It is composed of six graduated charts arranged in progression. Each chart is composed of 4 calisthenic exercises and one running activity, always performed in the same order and in the same maximum time limit of 11 minutes. As progress from chart to chart is made, there are slight changes in each basic exercise with a gradual demand for more effort. The program aims at muscular development in strength and endurance and at cardio-respiratory fitness (30:16).

h) Circuit Training - As employed in this study circuit training is an intensive exercise program consisting of 13 exercise stations always undertaken in the same order. Arrangement is

in a circular pattern so designated to enable an individual to proceed from one station to another without undue local fatigue. It aims at the progressive development of muscular and circulo-respiratory fitness through the principle of progressive loading. Six graduated exercise levels of increasing intensity are provided. Progress from level to level is realized when the individual accomplishes 3 tours of the circuit in 25 minutes completing the necessary number of repititions at each station. Weights are used at 7 stations.

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# CHAPTER II

## REVIEW OF THE LITERATURE

The quantity of published material concerned with the study of cardio-respiratory function is enormous. The present review contains only references selected for their special relevance to the problem under investigation. The literature will be considered as follows:

a) Directly related studies comparing the effects of two or more exercise programs on selected cardio-respiratory parameters.

b) Literature concerned with the effects of exercise or training for normal young adult males, on heart rate, oxygen intake, the respiratory quotient, and on the resting maximum breathing capacity.

c) Literature pertaining to the use of treadmill performance as a standardized test for determining cardio-respiratory fitness.

Directly Related Literature. Few studies are available which specifically compare and evaluate the effectiveness of concomitant exercise programs on cardio-respiratory measures. Particularly lacking are comparisons between such exercise programs which vary in intensity and duration over similar periods of time. The following seem germane:

Wilbur (1), in 1943, compared the effects resulting from two programs of physical education on the physical fitness of

366 college freshmen. The Sport's Program consisted of a composite of boxing, wrestling, track and field, soccer and swimming. The Apparatus Program included most aspects of gymnastics. Of the seven items included on the test battery, the quarter mile run was employed as an index of cardio-respiratory endurance. Following three testing periods conducted before, during and upon completion of the physical education programs the investigator was unable to establish the superiority of either program to produce significantly greater improvement in cardio-respiratory fitness. The study failed to reveal the intensity of participation by the subjects in the two programs.

In 1950, Capen (2) employed the time of a 300 yard run as a measure of circulo-respiratory fitness. One group of subjects performed 14 weight-lifting exercises for 40 minutes, twice a week for 11 weeks. A second group participated in a strenuous conditioning program of gymnastics and running for a similar period. Re-test data lead to the conclusion that weight-training was as effective in developing cardio-respiratory fitness as a program emphasizing endurance activities.

Sinisalo and Juurtola (3) compared the physiological effects of two methods of ski-training in 1957. Interval training and constant speed programs were studied over a period of 8 weeks. The subjects participated in 3 one hour training sessions weekly. The investigators found that skiing

per se produced statistically significant decreases in pulse rate both during work ($p < .001$) and during recovery ($p < .01$). There was no significant change in vital capacity. No statistically significant difference was reported between the two training methods.

Nagle and Irwin (4) investigated the effects of two systems of weight-training on circulo-respiratory fitness in 1960. Parameters investigated included heart rate, respiratory exchange ratio and ventilatory efficiency. Three groups of 20 subjects each were tested on a bicycle ergometer performing moderate and all-out exercise before and after an 8 week experimental period. Two of the groups participated in two different techniques of weight-training. The control group was restricted to bait casting or archery. Despite some indication of weight-training effects, statistical treatment of the data revealed no significant differences among the three groups.

Durnin et al (5) conducted a pertinent study in 1960 designed to determine whether improvement in physical fitness could be gained through varying degrees of exercise conducted over very short periods. Forty-four untrained airforce personnel, mean age 22 years, were randomly divided into 4 groups. Group 1 walked 10 km/day, or once around a 10 km circuit; Group 2 walked 20 km/day; Group 3 walked 30 km/day and Group 4 acted as control. Training continued for 2 con-

secutive periods of 5 days with an intervening 1 day intermission for testing. Each subject was tested on a treadmill operating at 5.6 km/hr and 10% grade for 15 minutes before, during and after the exercise programs. Following the first 5 minutes of testing, pulmonary ventilation, oxygen consumption and heart rate were measured continuously. Heart rate was also recorded for 10 minutes during recovery. The group walking 20 km/day showed the most marked improvement in cardio-respiratory fitness. A definite general improvement in fitness was observed in all three exercise groups compared to control. It is interesting to note that significant changes in cardio-respiratory fitness could result in only 10 days of relatively moderate work and that the greatest improvement was observed in a group not performing the hardest work.

In 1961, Watt (6) studied the effects of two different types of exercise programs to determine which was the most effective in increasing the physical fitness level of low-fitness college freshmen. One program consisted of calisthenics, weight-training exercises, running activities and games of low organization. The second program was a 9 station Circuit Training Course to which games of low organization were also added. Scores obtained on a Composite Fitness Test Battery served as the principal criteria by which fitness improvements of the two groups was compared. The 300 yard run was employed as a measure of cardio-respiratory fitness.

After testing 38 subjects in September and re-testing in December, the investigator observed that the greatest gains in both groups were those attained in cardio-respiratory function. He concluded that improvement as measured by this cardio-pulmonary test could be increased significantly by participation in either of the two programs.

It is apparent then, with the exception of Durnin's study, that while all programs promoted some degree of cardio-respiratory improvement none of the comparative studies was able to statistically establish the superiority of one particular program in this capacity.

The Effect of Exercise on Heart Rate. The behaviour of the heart rate before, during and after an exercise, and following a period of training has been studied extensively. Cureton states:

> Pulse rate does not represent a complete test of circulatory-respiratory fitness but the pulse is the easiest to measure and is the most reliable of the physiological variables which reflect the internal bodily efficiency in response to exercise (7:162).

Circulatory adjustments to the stress of exercise and the manner in which resting levels are re-established are important aspects of exercise physiology since blood flow is closely related to oxygen transport to the tissues (8:28).

The first physical educator to conduct systematic studies of pulse rate as it is related to exercise and phy-

sical fitness appears to be Bowden (7:165). Bowden (9) concluded that the behaviour of the pulse rate was attributable to (a) the speed of the exercise (b) the effort put forth (c) the physiological condition of the subject (d) age and (e) the posture and mental state of the subject. Since 1903, these areas have been intensively investigated.

Taylor (10) studied the performance of 2 moderately trained subjects on the bicycle ergometer as they responded to work loads ranging from 636-1191 kg m/min. The subjects were in a post-absorptive state and performed at a constant rate of 65 rpm 3 times weekly for a period of 2 months. Each of the 24 experiments conducted lasted 40-50 minutes. Heart rate was determined with a stethoscope every 5 minutes. He observed that, ". . . heart rate does not, in the typical case, reach an absolutely steady state but continues a slow upward drift throughout the 45 minute work period" (10:28). Fraser _et al_ (11) noted that pulse rates for 41 subjects walking on a treadmill at 3 mph and 5% grade tended to, ". . . quickly reach a plateau during steady work" (11:194). Christensen's findings (12:203) agree with Taylor where exercise is severe and with Fraser for moderate activity. This observation is generally supported by the literature.

Taylor also found that a linear relationship exists between heart rate and work load (r = .97) (10:28). This is in agreement with Bock _et al_ (13:149) and is supported by More-

house (14:28), Christensen (12:203) and Balke (15:677).

Exercise heart rate was found to be a better indication of fitness than recovery heart rate (16:200). Nagle and Bedecki (17) studied all-out performance time on the treadmill and observed that the exercise heart rate improves as a measure of circulo-respiratory capacity as it increases. Billings and associates (18:1005) found that the heart rate response during submaximal progressive exercise on the treadmill indicates accurately the subjects' capacity for more strenuous work provided the cardiovascular system represents the limiting factor for continued exercise.

After a period of training, heart rate accelerates less for a given task (7:273), (10:28), (13:149), (19:167), (20:143), (21:523). Brouha and Heath (22) compared pulse rate measurements of 129 college students performing on a treadmill at 7 mph and 8.6% grade with those similarly obtained from a group of athletes. Pulse rate was recorded by a cardiotachometer. They concluded: "For a run of the same duration, the maximum pulse of trained subjects is usually lower than that of untrained subjects" (22:475).

Durnin _et al_ (5:163) found that heart rate determined during treadmill exercise indicated no significant change in the control group but all exercise groups experienced a highly significant ($p < .01$) lowering of their exercise heart rate. Three groups of subjects walked 10, 20 and 30

km/day for 10 days. Recovery heart rate was significantly lowered only in the group walking 20 km/day ($p < .05$) and only during the interval 2 - 2.5 minutes after exercise. Fletcher (23) found resting pulse rates ranging from 48 beats/min. for athletes to 90 beats/min. for sedentary individuals prior to daily step-up exercises. As endurance improved the mean resting pulse was lowered 16% with rates of change of 2-3% per week. Initial peak heart rates ranging from 140-216 beats/min. ". . . became rare" (23:765) as training advanced.

Taylor studied exercise heart rate curves and observed: "The most striking difference between high and low fitness subjects is the lower, flatter and straighter curves of the former" (16:207). In agreement with Steinhaus (24), Taylor concludes: "In general, though there are exceptions, the individuals of greatest capacity show lower heart rates per unit of work" (10:34).

It is generally conceded that trained individuals have a low resting pulse rate (19:167), (21:523), (24:112), (25:322), (26:155), (27:422). Cotton (28) in particular, reports unusually low pulse rates among athletes. Mean basal pulse rates found were (a) 47 for championship swimmers (b) 66 for normal young men with no athletic history (c) 63 for young men with average athletic history (d) 57 and 53

for men with greater and superior athletic backgrounds respectively, and (e) 50 for Olympic athletes.

The search for practical tests of physical fitness has emphasized the resting pulse rate because of convenience of measurement (8:28). Henry reports that consideration of the resting circulation is of importance since it may reflect, indirectly, ". . . physiological changes resulting from training that are advantageous during exercise" (8:28).

In opposition, Brouha and Gallagher (29) state that resting heart rate is not an important factor in this regard:

> Research has shown that the initial heart rate of healthy young men does not have a significant relationship to an individual's physical fitness; his fitness depends on the rate at which his heart slows after exercise and not on how fast it may have been beating before he began work (29:25).

In support of this statement, Brouha and Heath (22:476) report that: "With few exceptions no satisfactory relationship was found between basal pulse or sitting pulse and the capacity to perform hard work." This is confirmed by several other investigators (27:422), (30), (31:175), (32:367).

Cureton (7:167) states: "A quick recovery of the pulse rate to the starting standing normal is one characteristic of fitness. It is one of the most valid tests if the exercise is hard enough." Several investigators concur (3:293), (20:141), (22:477), (29:28), (30:28). Michael and Gallon (33)

observed that recovery pulse rate made significant changes in 3 weeks (.05 level) and highly significant changes after 6 weeks (.01 level) when 17 varsity basketball players were studied over a period of 16 weeks of training and after 10 and 20 weeks of detraining. A one-minute step test was administered to each subject every 3 weeks. Within 10 weeks of detraining, resting and recovery pulse rates returned to their pretraining levels. The resting pulse rate did not change significantly during training. Billings _et al_ (18:1005) report that pulse rates during recovery from exercise may also be of some value in ranking subjects exposed to light or moderate work. They found, however, no correlation between heart rate pattern during recovery and the ability to sustain maximal or exhausting work. Knehr _et al_ (26:155) found that post-exercise pulse rates showed no training effect when the exercise is of maximal type, rather that training is reflected by increased duration of performance. Cogswell (27:423) and Durnin (5:165) concur.

Several investigators report the effect of extraneous influences on heart rate. Dill (34:273) states: "The heart rate particularly, responds sensitively to changes in external temperature and humidity, both in moderate and in hard work." More recent research does not support these findings (35:575). Cotton (28:42) points out the possibility that increasing familiarity of the subject with the investigator,

and the conditions of the experiment may result in an improved resting pulse rate. Darling (20:144) brings attention to a factor often overlooked in studying heart rate: "It must be remembered that many persons are poorly endowed with cardio-vascular and muscular systems and apparently cannot improve significantly." Brouha and Heath (22:476), later supported by Fraser et al (11:194) refer to the influence of emotional factors which tend to elevate the resting pulse rate. Morehouse (30:27) and Cogswell et al (27:429) observe that individuals with higher than average resting pulse rates tend to have higher than average post-exercise pulse rates and hence are penalized from the start in such measures of fitness. Wolf (36:476) indicates that postural changes during exercise performance or at rest produce changes in the pulse rate. The head down position tends to slow the pulse rate while pulse rate is elevated when the head is up.

Several investigators report peak heart rate levels attained during all-out exercise. In this regard Table I summarizes relevant findings and indicates the general trend.

The maximal limit of effective heart rate action remains to be evaluated. Over a wide range, Dill and Brouha (10:34) have shown that this limit is by no means uniform. Heart rates near 190 beats/min. are probably incompatible with effective cardiac output since in cases where this level is

TABLE I

DETERMINATION OF PEAK HEART RATE DURING EXERCISE

| Investigator & Ref.No. | Year | Age Range | Physical Classification | Type of Standardized Exercise | Intensity of Exercise | Range or Mean Peak Heart Rate (beats/min) |
|---|---|---|---|---|---|---|
| Knehr et al (26) | 1942 | Not Stated | Untrained College Students | Treadmill | 3.5 mph-8.6% followed immed. by 7mph-9.1-13.4% | 197 |
| Brouha & Heath (22) | 1943 | 17-22 | College Athletes & non-athletes | Treadmill | 7 mph - 8.6% grade | 193 |
| Taylor (16) | 1944 | 19-26 | Coll. Stud. untrained 2 Coll. Athl. | Treadmill | 162 M/min. 5% inst. Grade w. 1% inc/min. | 198 |
| Morse et al (37) | 1949 | 14-17 | Untrained Active Boys | Treadmill | 6 - 7 mph 8.6% grade | 196 |
| Astrand & Rhyming (38) | 1954 | 18-30 | Trained Adults | Treadmill<br>Step-Test<br>Bicycle Ergometer | 10 Km/hr, 1°<br>40 cm, 22½/min.<br>900-1200 kg M/min | 195 |
| Hedman (39) | 1957 | 23-35 | Trained Skiers | Skiing | To Exhaustion | 160-190 |
| Slonim et al (40) | 1957 | 18-25 | Trained Naval Cadets | Treadmills | 3.5 mph 20-25% grade | 188 |
| Fletcher (23) | 1960 | 20-46 | Athletic & Sedentary Adults | Step-ups | 22" bench 30 cycles/min | 140-216 |
| Hettinger et al (41) | 1961 | 20-40 | Policemen Moderately Active | Bicycle Ergometer | 50 RPM at pre-determined load | 183 |
| Nagle & Bedicki (17) | 1962 | 18-36 | College Athletes & Non Athl's. | Treadmill | 3.5-5.5 mph Grade inc. to 10% | 180 |

reached the subject is near exhaustion (10:34).

In conclusion, Taylor's observations are pertinent:

> . . .the heart rate pattern should be looked upon as a sensitive indicator of the trend of adaptation to the exercise, an integral of many known and unknown differences affected by respiratory and neuromuscular factors as well as those intrinsic in the heart action itself (16:208).

The Effect of Exercise on Oxygen Consumption. Taylor states (10:35):

> The rate of oxygen consumption is a highly significant physiological variable not only because it represents the physiological cost of the work but because it gives evidence of the transport capacity of the circulatory and respiratory mechanisms.

Bruce *et al* (42:428) found a high correlation (r = .938) between oxygen consumption and oxygen transport. Oxygen consumption during strenuous exercise is proportional to the blood flow and is modified by the amount of oxygen taken out of the blood by the active muscle tissue. This amount may exceed resting values ten to sixteen times (31:437), (38:218), (43:66), (44:83). Astrand (25:308) observes: "Provided that the mechanical efficiency does not vary too much, the individual's capacity for oxygen intake should be decisive in determining his ability to sustain heavy prolonged work."

If the exercise is moderate and uniform in nature, the oxygen intake rises gradually then tends to plateau for the

duration of the exercise (43:66), (44:83). The transition from rest to work is characterized by a rapid rise in oxygen intake to a level corresponding to the amount of work performed (7:433). Mitchell _et al_ (45:538) found a linear relationship between workload and oxygen intake with progressively increasing workloads where sufficient time for recovery was permitted between increments.

It is generally conceded that a better utilization of oxygen is developed in the process of training (5:163), (7:431). McNelly observed:

> . . .during exercise the quantity of oxygen absorbed per 100 cc of air breathed was greater for the trained than the untrained subjects. This is true in spite of the fact that during the preliminary rest period there is no significant difference between these figures for the trained and untrained subject (46:101).

Knehr _et al_ (26:151) found a decline in the mean oxygen requirement during grade walking on the treadmill of 1.91 to 1.78 ls/min. over a 6 months training period. Astrand (25:314) with confirmation from Morehouse (44:87) explains that through training, efficiency can increase. Thus a relatively low aerobic capacity can be compensated for, to some extent, if the athlete works economically.

Schneider and Crampton (19:169) studied the performance of athletes and non-athletes on the bicycle ergometer and concluded that approximately equal amounts of oxygen per

square meter of body surface was consumed by both groups. Freedman et al (47) concur where the work is sub-maximal. Studying cross-country athletes before and after training they observed:

> No differences attributable to training were seen in the way a trained or untrained athlete meets the tissue demands for an increased supply of oxygen during exercise up to levels requiring about 2 liters of oxygen intake per minute (47:46).

Balke and Ware (15:83) and Taylor (10:37) are in agreement with Hettinger et al (41) that the, ". . .maximum oxygen uptake (aerobic capacity) is probably the best measure of a person's physical fitness providing the definition of physical fitness is restricted to the capacity of the individual for prolonged heavy work" (41:153). Astrand and Rhyming (38:221) and Cureton (7:329) state that a more meaningful measure of fitness to do heavy work is the rate of oxygen intake per kilogram of body weight per minute. Cureton reasons that a large man will require more oxygen than a small man: "When weight is divided out the relative efficiency (the rate at which oxygen can be supplied for each kilogram of body weight) is more clearly reflected and is not just a reflection of the body weight" (7:329).

It is generally agreed that maximum oxygen uptake can be increased with training (20:141), (26:152, (43:67), (44:93), (54:428), (55:1695).

Several investigators have determined maximum oxygen uptakes using a variety of techniques. Table II summarizes their findings.

Oxygen consumption is closely proportional to time of treadmill running (7:315). Cureton (7:329) computed correlations of .87 and .34 for gross oxygen intake and gross oxygen intake/kgm/min respectively with time for all-out performance on the treadmill. He observed, ". . .the rate of gross oxygen intake/kgm/min is an excellent measure to use to rate the circulatory capacity of an athlete" (7:336). Taylor (16:211) found that $O_2$%, $CO_2$% and $O_2$ consumption showed moderate correlations with running time of .34, .06 and -.20 respectively for sub-maximal work on the bicycle ergometer and .45, .44 and .39 respectively for maximal work.

Hill et al (48), Krogh and Lindhard (49), Berg (50) and Andersen (51) agree that after strenuous work the $O_2$ recovery curve is characterized by a rapid initial fall of a few minutes duration followed by a gradual decline to the pre-exercise level which may last several hours: "After moderate exercise the recovery curve is composed entirely of the first component" (50:597). Berg (50) determined the reliability and variability of the time constants of recovery from mild step-up exercise using the test-retest method for 38 male subjects. Reliability of $CO_2$ and $O_2$ recovery time constants were $.74 \pm .12$ and $.55 \pm .15$ respectively (50:609). The in-

TABLE II

DETERMINATION OF MAXIMAL OXYGEN UPTAKE

| Investi-gator & Ref.No. | Year | Physical Classification of Subjects | Age | Method of Determining Max. $O_2$ Uptake | Mean Maximum $O_2$ Uptake l/min. |
|---|---|---|---|---|---|
| Knehr et al* (26) | 1942 | Untrained Students | Not Stated | Treadmill 7 mph grade inc. from 9.1-13.4% | 3.69 |
| Morse et al (37) | 1949 | Active Boys | 13-17 | Treadmill 6-7 mph 8.6% grade | 44.8 cc/Kgm/min.(13) to 50.9 cc/Kgm/min.(17) |
| Astrand & Rhyming (38) | 1954 | Highly Trained Athletes | 20-30 | Bicycle Ergometer 1200 Kgm/min. | 4.15 ± 0.28 |
| Taylor et al (56) | 1955 | Trained & Un-trained Adults Students Soldiers | 18-35 | Treadmill 7 mph 10% grade | 3.60 ± 0.51 |
| Buskirk & Taylor (57) | 1957 | Sedentary Students Soldiers | 18-29 | Treadmill 7 mph Individ. Det. grades | 3.44 ± 0.46 |
| Hedman* (39) | 1957 | Highly Trained Skiers | 23-35 | Skiing to Exhaustion | 4.33 |
| Slonim et al (40) | 1957 | Trained Naval Cadets | 18-25 | Treadmill 3.5 mph 20-25% grade | 4.05 ± 0.39 |
| Mitchell et al (45) | 1958 | Untrained Active Adults | 20-43 | Treadmill 6 mph Grade inc. 2½%/run | 3.27 ± 0.50 |
| Hettinger et al (41) | 1961 | Moderately Active Policemen | 20-40 | Bicycle Ergometer 50 rpm Indiv. Det. Load | 2.39 ± 0.30 |

*Indicates peak $O_2$ intake during maximal exercise.

vestigator observed: "Different intensities and duration of moderate exercise have no effect on recovery constant which permits comparison of recovery times between individuals who perform varying degrees of work" (50:609). The literature supports the findings of Berg (50:603) and Erikson (52:188) that recovery time for oxygen uptake is less than that for carbon dioxide output with $CO_2$ recovery time showing greater interindividual differences. Average $CO_2$ and $O_2$ recovery times are more rapid in trained than in untrained individuals (50:609), (51:112), (52:194), (53:219).

In agreement with Balke and Ware (15), Nagle and Bedecki (17), Billings _et al_ (18), Dill (31) and Taylor (10) concluded:

> It seems that the subjects maintain a linear increase in heart rate, $O_2$ consumption, % $CO_2$ in expired air and total ventilation up to a certain load after which these functions tend to fail to maintain the increase while ventilation is augmented excessively. The crest load at which these functions can maintain their linearity varies both with the specific function and with the individual subject (10:38).

_The Effect of Exercise on the Respiratory Quotient (R.Q.)._ It is apparent that where a critical evaluation of the respiratory quotient is concerned, a clear distinction must be made between the measured quotient and the true metabolic quotient. It is recognized that there is only one respiratory quotient. The quotient as measured, however, may not

reflect the concurrent oxidation in the tissues. In agreement with Richardson's observation (58:74) it is advisable to designate the observed quotient as the measured or ventilatory quotient and the quotient due to oxidation as the true or metabolic quotient. Exact equivalence of the R.Q. as found in expiratory air and the R.Q. of the tissues is observed only when equilibrium exists between the ventilatory and metabolic rates (13, 58, 59). These requirements are realized under basal conditions or during the steady state of exercise. A better term to use where experimental conditions cause a deviation from this situation would be the respiratory exchange ratio.

Krogh and Lindhard (49), in order to observe the behavior of the R.Q. during exercise, experimented with a bicycle ergometer using work periods of variable lengths and intensities. They found:

> The most characteristic feature met with seems to be a marked rise, the more pronounced as the work becomes more and more heavy, followed by a fall to subnormal values, i.e., values below .7 (49:434).

Alveolar samples drawn just prior to, and after the experiments showed that the R.Q. rose to higher levels than those assumed during exercise.

Bock _et_ _al_ (13) similarly employed the bicycle ergometer to study 3 sedentary subjects and 1 highly trained

marathoner during 20 minutes of sub-maximal work. The subjects were tested in the basal and non-basal states. Two minute samples of expired air were collected after 5 minutes of exercise and at irregular intervals thereafter for 60 minutes. The investigators noted that the R.Q. remained near .96 during the interval from 5-25 minutes after exercise began, then gradually fell. A particularly rapid fall in the R.Q. was noted during the period of recovery with a return to near basal conditions in approximately 15 minutes. The authors noted:

> A rise in R.Q. occurs as the metabolic rate increases until a limiting value of about unity is reached in the hardest work which can be carried on in a steady state (13:168).

This conclusion is in accord with Krogh and Lindhard and is widely supported by most other researchers. It was also observed that where the oxygen consumption was below 1500 cc/min. the value of the R.Q. tended to remain below .95.

Best, Furasawa and Ridout (60), in agreement with Hill *et al* (48), demonstrated that the severity and duration of the exercise greatly influences the R.Q. In exercise of short duration, the R.Q. is, in general, proportional to the severity of exercise and consequently to the excess metabolism and oxygen consumption. In very severe exercise the investigators state the R.Q. may reach a value as high as 1.7. Hill *et al* (48:467) report an R.Q. of 2.03 in one of

their subjects. Gould and Dye (6:160) concur, reporting an R.Q. of 2.0 following severe activity. After attaining these high values, Gould and Dye observed the tendency of the R.Q. to fall slowly, dropping as low as .6 or .5.

Dill, Talbot and Edwards (62) employed the treadmill to test 10 normal males not in active training. The subjects ran for 20 minutes at 9.3 km/hr which resulted in an increased metabolic rate 8-12 times the resting rate. Each subject breathed continuously through a mouthpiece until the 9th minute of exercise, and again from the 12th to 13th minutes. One minute alveolar gas samples were collected at rest and during the 4, 8, 13, and 17th minutes of work. The investigators found a mean resting R.Q. of .80. Where little or moderate lactic acid concentration was observed only slight changes in R.Q. values were apparent, the average value approximating .91. A slight fall in R.Q. was reported as work continued, contrary to the findings of their predecessors. Where extreme fatigue and rapid accumulation of lactic acid occurred, the R.Q. was observed to climb in excess of unity.

Morse and associates (37) worked with 110 boys 10-17 years old. The subjects participated in (a) a sub-maximal treadmill test walking for 15 minutes at 3.5 mph and 8.6% grade, and (b) a maximal work test designed to bring about exhaustion in 2-5 minutes. Boys 10-13 ran at 6 mph, 8.6%

grade, boys 14-17 at 7 mph and similar grade. During the walking test the R.Q. during exercise varied between .83 and .89 for the younger group and remained steady around 188 for the older boys. The graded running test produced mean R.Q. values of 1.01 (10-13 year olds) and 1.15 (14-17 year olds).

Daugherty's study (63) concerned 16 normal males 20-25 years old. The subjects were pre-selected on the basis of time spent normally in moderate or strenuous physical exercise. Each subject ran on a treadmill for 6 mins. at speeds of 2.3, 3.5, 4.6 and 6.9 mph to exhaustion. The author observed R.Q.'s ranging from mean values of .72 at rest to .95 during maximal work, 1.06 after 15 minutes of recovery and .70 after 120 minutes of recovery. This is in accord with previous findings.

Cureton (7:360) investigated the variations of the R.Q. during exercise and the subsequent relationship to training. Results were derived from testing a single subject 17 times over a period of 6 months. The subject was tested at different rates of treadmill work following a variety of exercises. From a resting R.Q. of .80 the subject's R.Q. rose to 1.12 during severe work. The R.Q. ranged between these values for moderate prolonged exercise. In agreement with the early research (49:435), Cureton observed that the R.Q. was always higher in the first recovery bag than during

exercise, rising as high as 1.52 for high energy exercise. During subsequent recovery, the R.Q. dropped back to the resting level and, ". . .usually below it to levels as low as .56" (7:366). The subject attained a relatively high trained state by the end of the testing period and a drop in the resting R.Q. for .80 to .66 was noted. Similarly the R.Q. dropped throughout the subject's performance and recovery times. The findings that for a trained person the R.Q. will be lower than that for an untrained person is supported by several other researchers, notably Bock _et al_ (13:156), Steinhaus (24:131), Hedman (39:319) and McNelly (46:101).

Hedman's subjects (39) performed work for 2.5 hours in the form of ski running at a constant speed on a 750 meter circular track set on level ground. The 4 well trained subjects, one a championship cross-country skier, worked to exhaustion. All subjects fasted for 12 hours prior to exercise. Earlier investigations (13:316) indicated that the R.Q. during prolonged work tended to decrease during the course of the work. Hedman's data does not agree. His subjects demonstrated very small variations in their R.Q. He concluded that the R.Q. remains high as long as the work intensity is high. The R.Q's fell continuously for his subjects during recovery up to 6.5 hours.

Crakes (64) studied the effects of an all-out run on

the treadmill for 11 well trained milers. His subjects ran at 10 mph on a 10% grade for 2:09 to 3:56 minutes. He noted (a) resting R.Q.'s from .72-1.30, (b) performance R.Q.'s from .85 - 2.23, (c) recovery R.Q.'s after 3 minutes 1.13 - 1.60, and (d) final recovery R.Q.'s of .67 - 1.33. His data indicated higher R.Q.'s for the faster runners, a finding, he observes, not reported in any other study.

The Effect of Exercise on the Maximum Breathing Capacity. Few studies have investigated the effect of systematic exercise on the resting maximum breathing capacity. Three studies seem pertinent.

Lewis and Morton (65) tested the effects of exercise on the MBC of 5 medical students. A Tissot spirometer was used. The subjects participated in 3 successive trials each of 15 seconds with a 45 second rest period between attempts. The subjects walked for 5 minutes on a treadmill at 4 mph and 3.5% grade, then undertook the 3 MBC tests. The investigators found an increase in the MBC from a mean value of 193.1 l/min. at rest to a mean 205 l/min. after exercise, ($p < .001$). They concluded that the MBC is increased during hyperpnea following exercise.

Freedman et al (47) studied three cross-country athletes performing standardized work on a bicycle ergometer and during a step test in order to investigate the cardio-respiratory effects of training on athletes. Two of the subjects

were studied in an untrained state and again after 2 months of strenuous activity. MBC's were determined according to Baldwin (66). The mean resting MBC for the trained athlete was 178 l/min. For the other 2 subjects, ". . .the increases in maximum breathing capacity found after training was complete . . . are definitely significant" (47:45). The level of significance was not stated. MBC's increased from 160 - 202 l/min. or 26%, and from 165 - 202 l/min. or 22% respectively. The investigators attribute the gain to an ". . .increasingly efficient utilization of the musculature of the thoracic bellows" (47:45).

Balke and Clark (67:84) also report an increase in the MBC during work on a treadmill following 8 - 12 weeks of training.

Ogilvie et al (68) studied the MBC of hospital patients with normal chests while exercising on a motor driven treadmill for 3 minutes: "The severity of the exercise was such that further increase was prevented by shortness of breath" (68:101). Mean age of the group was 29.4 years. The Douglas Bag technique was used with the subjects breathing at rates of 40, 60, 80 and 100 breaths per minute in time with a metronome. These results were compared with those obtained by the subjects' voluntary breathing rates. The order of the tests was randomly assigned. The mean resting MBC's were observed to be 113.9 l/min. at 40 breaths/min., 128 l/min.

at 60 breaths/min., 130.2 l/min. at 80 breaths/min., 143 l/min. at 100 breaths/min. and 149.6 l/min. for the voluntary tests with a mean rate of 96.6 breaths/min. It was observed that the maximum volume of air was respired during the voluntary trials. The results concur with Bernstein et al (69) who established that the MBC is dependent on the rate of breathing, the largest values being obtained at a level around 100 breaths/min.

The experimental techniques and findings of 13 other investigators, concerning the resting MBC, are summarized in Table III. Several pertinent observations are revealed as the result of their research.

Motley (80:103) states, "The value of the MBC measurement as a test of pulmonary function is recognized by all individuals actively engaged in pulmonary function studies at the present time." Unanimous agreement was found with this statement by the investigators reviewed. A serious limitation of the test, however, is revealed by Comroe (18:366) and Comroe et al (82:130), and which is generally supported by other researchers.

> Normal figures obtained in different laboratories vary as much as 32% according to the type of apparatus used and the resistance it offers to breathing. Until similar apparatus and procedures are employed universally it seems inevitable that each laboratory must calibrate its own apparatus and secure its own normal standard values.

TABLE III

METHODS OF DETERMINATION OF THE MAXIMAL BREATHING CAPACITY

| Investigator | Ref. No. | Year | No. of Subjects | Mean Age or Range | Type and Physical State | Experimental Device Used | Position of Subjects | Duration of Tests (Secs.) | Interval Between Tests on Same Trial (Mins.) | Prescribed Rate of Breathing for Max. Move of Air (Breaths/Min) | Method of Controlling Breathing Rate | Mean MBC 1/min. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cournand et al | 70 | 1939 | 20 | 27.9 | Untrained Normals | Spirometer | Standing | 15-30 | Not Stated | Voluntary (40-60) | Individual Interpretation | 154.0 |
| Baldwin et al | 66 | 1948 | 17 | 25.5 | Untrained Patients, Normal Chest | Spirometer & Douglas Bag | Standing | 15 | Not Stated | Voluntary | Individual Interpretation | 126.0 |
| Gilson & Hugh-Jones | 71 | 1949 | 4 | 35.0 | Untrained Patients, Normal Chest | Spirometer | Seated | 15 | Not Stated | Voluntary | Individual Interpretation | 122.5 |
| D'Silva & Mendel | 72 | 1950 | 15 | 23.7 | Untrained Meds. Highly Motivated | Spirometer | Standing | 12-24 | 10 | 50 | Metronome | 188.0 |
| Grey et al | 73 | 1950 | 194 | 24.0 | Untrained Meds. | Spirometer | Standing | 20 | Not Stated | Voluntary | Individual Interpretation | 166.8 |
| Bernstein et al | 69 | 1952 | 22 | 23.7 | Untrained Meds. Highly Motivated | Spirometer | Standing | 12-24 | 10 | 70 | Metronome | 187.0 |
| Ferris et al | 74 | 1952 | 161 | 5-18 | Untrained Boys | Spirometer | Seated | 15 | 1 - 2 | Voluntary | Technicians Audible Instr. | 46-155 |
| Stocks & Kennedy | 75 | 1953 | 5 | 25.2 | Untrained Normals | Spirometer | Seated | 15 | Not Stated | Not Stated | Not Stated | 143.8 |
| Needham et al | 76 | 1954 | 43 | 18-30 | Untrained Normals | Douglas Bag | Seated | 15 | 5 | Voluntary (50 +) | Individual Interpretation | 137.0 |
| Shephard | 77 | 1956 | 20 | 28.7 | Trained Air-Force Personnel | Pneumotachograph | Standing | 15 | 5 | 90 | Metronome | 169.0 |
| Bartlett & Specht | 78 | 1957 | 3 | 20-49 | Untrained Normals | Douglas Bag | Not Stated | 15 | Not Stated | 60-120 & Voluntary | Metronome & Indiv. Interp. | 166.5-190.9 |
| Rusch & Brant | 79 | 1957 | 7 | 24.0 | Trained Wrestlers | Spirometer | Standing | 15 | Not Stated | Voluntary | Individual Interpretation | 166.0 |
| Slonim et al | 40 | 1957 | 33 | 18-25 | Trained Naval Cadets | Spirometer | Standing | 30 | Not Stated | Not Stated | Not Stated | 173.0 |

Accordingly, therefore, reduction or increase in MBC must be large to be considered significant: "Usual practice is to regard ±20% of the normal predicted value as the normal range" (83:22).

D'Silva and Mendel (72:328) in agreement with Baldwin et al (66:251), report that the degree of individual co-operation was found to have a significant effect on determining the MBC. Bernstein (69:261), Needham (76:314), and Comroe (82) concur observing that this factor greatly reduces the effectiveness of the test.

Gilson and Hugh-Jones (71) found that considerable variation exists between an individual's performance in successive experiments conducted during the same day or on subsequent days. D'Silva and Mendel (72:327) state that when respiratory rate is controlled variability on any one day is small. Shephard (77:3) observed that the MBC does not change by more than 10 liters over a wide range of respiratory rates. He states, ". . .the total alveolar ventilation is very similar whether a few deep breaths or many shallow breaths are taken" (77:6). Shephard also concludes that the use of a regulatory device for establishing breathing rates produces a smaller and more variable ventilatory volume because of a diversion of concentration. Grey et al (73:677), Knowles (83:21) and Rossier (59:135) agree that the depth and rate of breathing should be deter-

mined by the subject himself. Comroe _et al_ (82:129) state, ". . .as a rule maximum ventilation can be attained only by voluntary effort."

Knowles (83:21), Comroe (81), and Grey (73:678) found that the learning technique is largely completed after the first trial. Gilson and Hugh-Jones (71) report no evidence of a learning effect. Ferris and associates (74:660) observed a substantial training influence with very young subjects, which, in itself, could account for this finding.

Grey (73), in agreement with Baldwin (66) found that the standing MBC is 3-5% higher than when seated.

Baldwin _et al_ (66) also found a significant negative correlation between MBC and age (-.72), height (-.43), and with body surface and age (-.74). Ferris (74) recommends the calculation of MBC be based on age, height, weight and body surface area for young groups.

_The Use of the Treadmill as a Test of Cardio-Respiratory Fitness_. Exercise tests are used extensively but differ widely in detail consequently the comparison of results obtained from different laboratories is frequently difficult (85:391). If submaximal tests are employed, the intensity and duration of the exercise cannot exceed the capacity of the poorest subject. Maximal tests must bring all subjects to a comparable degree of exhaustion (16:200). The tests should be simple and standard in order to minimize

skill and motivation (10:27). Varying requirements for tests of circulo-respiratory fitness are reported. Astrand and Rhyming (38:21) indicate that the type of work performed should engage the large muscle groups and the work level must be relatively high. Balke and Ware (15), Billings _et al_ (18), and Astrand (25) agree that:

> The work load should be gradually increased and the increase must not be made too rapidly as the organism must be given time to adapt itself to the demands of the work (25:323).

Cureton (7), Gallagher and Brouha (84) and Darling (20) recommend that the test be severe enough to insure a maximum blood flow:

> The test need not have to be a test at the very fastest running speed but it must be a maximal test which will overload the circulo-respiratory capacity enough to bring about complete exhaustion within 5 minutes or less (7:314).

Billings _et al_ observe that a major difficulty in exercise tests involving fixed work loads is the fact that a work load which may be light for athletes may be maximal for sedentary subjects (18:1004). Darling concurs (20:142) and therefore recommends a maximal test for all subjects. The exercise must also require a uniform rate of energy output for co-operative and non-cooperative subjects alike (20:142).

Astrand (25) suggests that it is not possible to present any quantitative data on the effects of training since physical condition prior to training and the intensity of

training per se, are factors difficult to define and reproduce. Durnin _et al_ (5:162) do not agree. They suggest that, ". . .physical condition before training can be deduced, at least in part, by the reactions of a group of subjects to a standardized exercise prior to training; and that there is little reason why the intensity of training cannot occasionally be controlled and defined." For precise research Erickson _et al_ (85) establish the superiority of the treadmill on the basis that (a) workload on the treadmill is fixed without any requirement for the subject to keep time, (b) skill and apparatus factors are at a minimum, (c) a larger total energy expenditure is obtained, (d) the work is automatically adjusted to body size.

The training factor is not a significant influence on improved treadmill performance time (18:1006), (20:140), (35:576), (85:393), (86:132). Erickson _et al_ (85:393) found that oxygen consumption measured during the second treadmill performance gives a valid figure which is not influenced by increased experience in treadmill walking. The investigators conclude, ". . .prolonged training (on the treadmill) does not produce a consistent improvement of efficiency for the duration of several months" (85:394).

Further investigation into factors which may influence treadmill performance was conducted by Durnin and Namyslowski (35). Ten men and ten women participated in 4 standardized

activities (a) lying (b) sitting (c) walking on a treadmill at 3.2 mph and zero grade, and (d) walking on a treadmill at 2.7 mph and 10% grade. The investigators concluded (35:576): (1) It is possible for many purposes to ignore the effects of time of day on the metabolic cost of any activity. (2) Tests conducted on different days had no effect on results. (3) There were no measurable effects due to changing external temperature and barometric pressure. (4) Training exerts a negligible effect within the limits of the experiment conducted. (5) Emotional aspects such as mild apprehension had little effect on gross metabolism.

Balke and Ware (15) developed a treadmill test frequently employed to determine an individual's work capacity. Their method requires that the subject walk on a motor driven treadmill at the rate of 3.4 mph with the grade increased one degree per minute. They feel that this increase in grade is so slight that functional adaptations to increased energy demands can be realized in a few seconds. After considerable study of the physiological responses to treadmill work they concluded that the time it takes for the heart to reach 180 beats per minute constitutes a valid test of circulo-respiratory capacity. The working hypothesis is that the pulse rate at any given work load closely reflects the status of the individual's work capacity. At 180 beats per minute the investigators observed signs of physiolo-

gical deterioration. While maximal work capacity usually reaches beyond this point, they feel that further work is not paralleled by further adequate functional changes. These findings have been confirmed by Nagle and Bedecki (17) and Billings et al (18). Balke and Ware report a test-retest reliability of .82.

Treadmill performance at 7 mph has been studied by several investigators (7, 22, 37, 56, 57). Seven miles per hour was selected by Taylor et al (56), ". . .since it is the slowest speed at which all subjects appear to be forced to maintain a running stride and it is slow enough to insure a wide range of capacity it can be tested satisfactorily" (56:75). Cureton states:

> At about 7 mph and 8.6% grade treadmill running, an ordinary healthy young man will develop approximately maximal blood flow. At rates of speed above 7 mph, all but the best athletes will "tense up" and the blood flow through the arms and legs and through the total heart lung circuit will be impeded, thus causing them to "tie-up sooner" than if they were able to hold a normal full running stride with good relaxation throughout the run (7:314).

Erickson and associates (85) summarize the results of systematic study of treadmill walking at 16 different combinations of speeds and angles over the range 2.5 - 4.0 mph and 0 - 10% grades. Their conclusions establish several advantages of the treadmill as a standardized exercise. (1) There is little training effect. (2) The small intrinsic

variations imply good reproductibility. (3) Comparatively small variations of speed and grade produce accurately measurable differences of energy expenditure (85:400). It is apparent then, that the treadmill has the possibility of wide application in fitness testing (20, 25, 42, 85).

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## CHAPTER III

## METHODS AND PROCEDURE

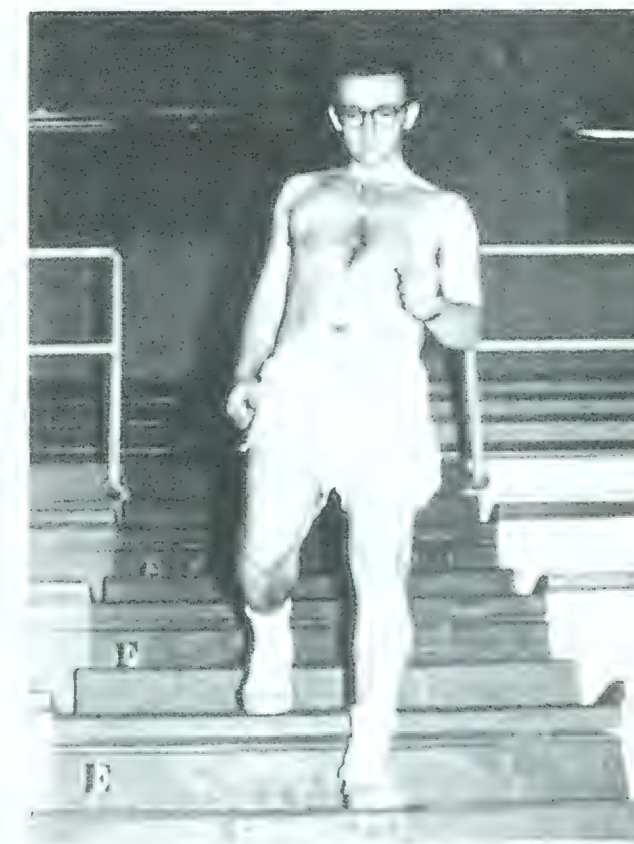
Selection of Subjects. Thirty healthy male subjects between 17 and 23, mean age 19.65 years, were selected at random from the general student body enroled at the University of Alberta. Although most subjects were active, none had participated in any regular or systematic exercise for one month prior to participating in the study. The subjects were equated on the basis of performance times on a preliminary Balke-Ware treadmill test (1) then randomly assigned to one of three groups of ten members each.

Group A - The subjects participated in the 5BX program of exercise (2:21-31). The group was divided into two sub-groups $A_1$ and $A_2$. Both groups participated in the first 4 exercises as specified. Sub-group $A_1$ was assigned running on the spot as their 5th exercise. Sub-group $A_2$ ran the specified distances as their 5th activity. The 5BX program was thoroughly explained and demonstrated. Each subject began at the B- level of chart #1 and progressed as rapidly as he could meet the standards designated at the maximum rate of 2 levels per day. Each subject trained five days a week, for five weeks. No training was done on week-ends or on testing days.

Group B - Members of this group participated in a 13

CIRCUIT STATIONS #3 MILITARY PRESS,
#10, BENCH PRESS

CIRCUIT STATIONS #9 JUMP CHINS,
#11 TRUNK EXTENSION



CIRCUIT STATION #13 STAIR RUNNING

station Circuit Training Program as outlined by Howell and Morford (3:12;App.B). Each subject began exercising at the Red #1 level. Training procedure was the same as for Group A.

Group C - Members of this group acted as control. They followed their regular daily schedule of activity but were requested to refrain from participation in any regular or systematic activity. Individual histories were kept concerning any physical activity in excess of usual daily practices. Testing was administered in the same manner as outlined for Groups A and B.

Testing Procedure. In order to familiarize the subjects with the equipment and testing procedures, one week prior to the initial test each subject walked the Balke-Ware test (1:676) to completion then ran at 7 mph on an 8.6% grade for a maximum period of 2 minutes following a 15 minute rest.

The subjects reported to the laboratory by appointment attired in gym shorts, socks and running shoes for the treadmill tests. The two treadmill tests were conducted 2 days apart. With few exceptions each subject was tested on the same day and at the same time of day during each testing period.

Testing was conducted immediately preceding the exercise programs, after 2.5 weeks and upon completion of the 5 week training period.

Three performance tests were administered during each

testing interval.

(1) The Balke-Ware Test (1:676) was administered as a test of sub-maximal work. The subject walked on a motor driven treadmill at a rate of 3.4 mph with a grade increase of one degree per minute until his heart rate reached 180 beats per minute.

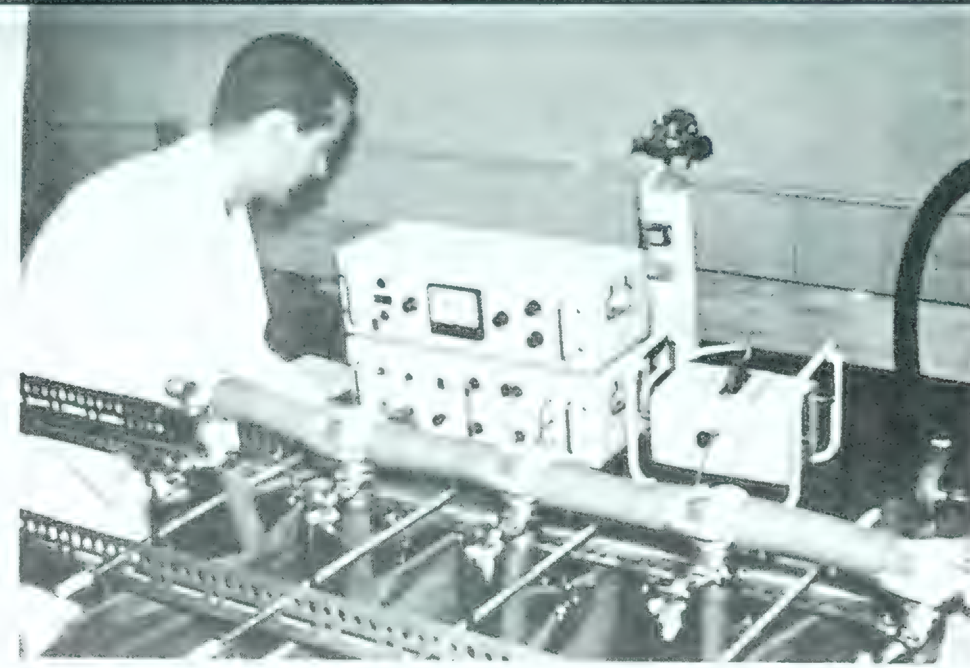
(2) A running test as outlined by Cureton (4:314) was administered as a test of maximal work. The subject ran at a speed of 7 mph on an 8.6% grade until muscular fatigue or exhaustion forced him to conclude the test.

(3) A Maximal Breathing Capacity test was administered as a test of respiratory function. Subjects reported to the Cardio-Pulmonary Laboratory at the University of Alberta Hospital by appointment. Each subject breathed into a closed circuit Godart Pulmotest Spirometer by means of a 'Y' valve connected to the spirometer by 1.5" rubber hosing. A clamp sealed off the nasal passage. All subjects stood during the test. Following specific instructions concerning the requirements of the test each subject exhaled maximally, the 'Y' valve was engaged to close the circuit and the test begun. After filling his lungs each subject proceeded to breath into the spirometer as deeply and as rapidly as possible for 15 seconds. With the exception of a brief preliminary exhortation according to D'Silva and Mendel (5:325) no further direction was given concerning the pattern of the rate and

depth of breathing that should be followed (6:667). Performances were recorded on a kymograph rotating at a speed of 60 mm/min. The temperature of the air in the spirometer was recorded continuously. Two trials were performed by each subject with a 10 minute rest between trials. The MBCs were computed from the kymograph records, corrected to BTPD, and the higher value obtained on the 2 tests selected as the subject's score. MBC tests were conducted on the Saturday of a test week.

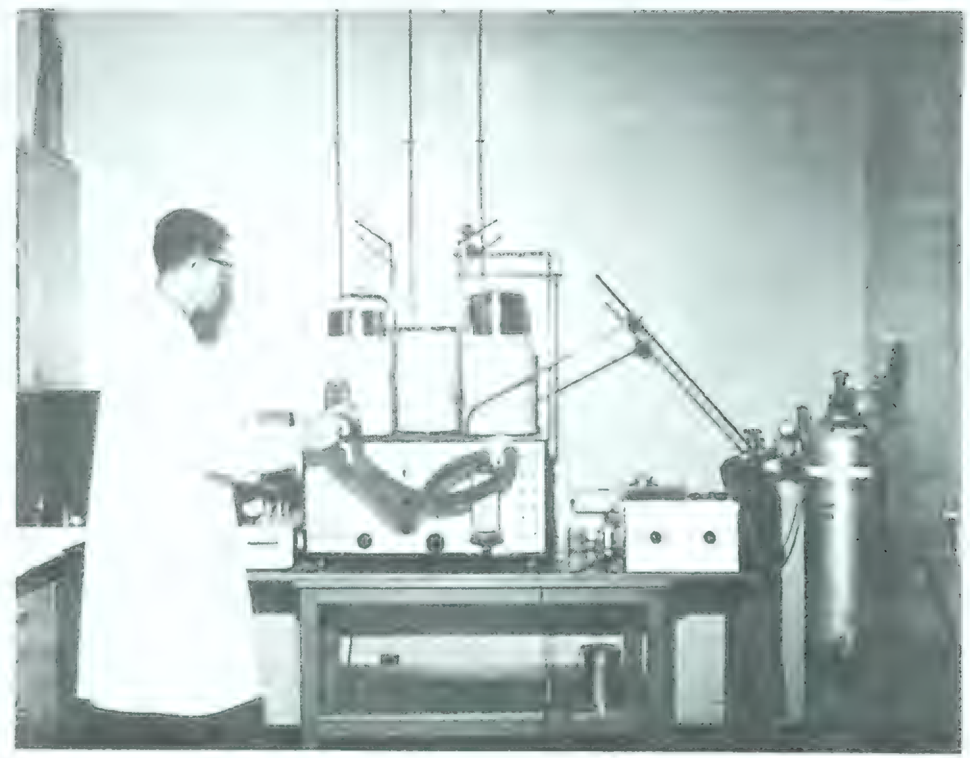
Heart Rate. A #51 Sanborn Electrocardiogram provided a continuous record of the subjects' heart rate. Two electrode plates were positioned by means of an elasticized band on the lateral aspect of the rib cage immediately below the intersection of a perpendicular line descending from the acromio-clavicular joints and a transverse line through the nipples. A third electrode plate was grounded in a similar manner in front of the left temple. Redux electrode paste was used to reduce skin resistance. This procedure provided a clear deflection with minimum interference during activity. The subject stood quietly on the treadmill until 2 identical pulse rates were obtained 15 seconds apart following a 2 minute waiting period. This figure was recorded as the resting heart rate and the test was then begun. During the Balke-Ware test, the heart rate was recorded every minute until it reached 165 beats/min. At this point it was recorded

TESTING APPARATUS FOR
TREADMILL PERFORMANCE TEST



GODART #KK CAPNOGRAPH
INFRA-RED $CO_2$ ANALYZER
AND DOUGLAS BAG SYSTEM

#802 AMERICAN GASOMETER,
COLLINS 1/15 H.P. PUMP,
#E-2 $O_2$ ANALYZER



GODART PULMOTEST
SPIROMETER

every 30 seconds. During the running test the heart rate was recorded every 30 seconds. Upon completion of the tests the subject remained standing on the treadmill and his recovery heart rate was recorded each minute for an additional 5 minutes.

Apparatus. To collect expired gas, the subject breathed through a rubber mouthpiece into an Otis-McKerrow 2-way valve connected by 1.5" rubber tubing to a series of 5-60 liter Douglas Bags. A 3-way #P-321 Thomas valve was placed at the junction of the airway leading from the mouthpiece into the Douglas bags. A second 1.5" rubber hose leading from this valve was connected to a Collins #P-553, 1/15 hp pump connected by 1.5" rubber tubing to a #802 American Gasometer. Expired air was drawn through the gasometer in this manner and volumes determined. Each Douglas bag was fitted with a #P-321 Thomas 3-way valve and serially connected to the next by 12" pieces of 1.5" rubber tubing. A clamp secured the 1/4" exit tubing leading from the neck of the Douglas bags. Expired air was drawn from the bags through this exit tubing via 1/4" vinyl hose into a Beckman #E-2 $O_2$ analyser and through a #KK Godart Capnograph infra-red $CO_2$ analyser. Both gas analysers were carefully calibrated prior to use and at regular intervals during the testing procedure.

Respired Air Analysis. During the Balke-Ware test expired air samples were collected at rest immediately prior to

treadmill performance, after 1, 5, and 10 minutes of exercise and when the heart rate reached 165, 175 and 180 beats/min. Since terminal performance time varies greatly with the individual, the heart rate limits specified were selected as more appropriate standardized intervals during which to study the cardio-respiratory variables considered for each subject.

During the running test expired air was collected immediately prior to exercise and after 1, 2 and 3 minutes of exercise. A terminal air sample was also taken when a signal from the subject indicated he was entering his last 30 seconds of work. Where distress was indicated previous to 3 minutes of performance a terminal sample was taken at that time and the 3 minute bag eliminated. Following the terminal gas sample each subject was encouraged to continue running an additional few seconds to insure a maximum effort.

Recovery samples were collected 1 and 5 minutes after exercise for both treadmill tests.

With the exception of the resting air sample which was taken for 30 seconds all gas samples were collected for 15 seconds only in order that the $O_2$ and $CO_2$ determinations would be close representations of the gas exchange at the specified intervals. The subjects remained standing throughout the tests.

Gas volumes were multiplied by 4 and corrected to STPD according to conversion tables from Peters and Van Slyke (7:27).

The volumes of inspired air, oxygen and carbon dioxide were computed according to Rossier _et al_ (5:48), and Consolazio _et al_ (11:335).

Statistical Treatment of the Data. The null hypothesis was that no difference existed between the means of the different variables considered.

Mean values for Groups $A_1$, $A_2$, B, and C for each of the three test periods were computed for

a) performance time during the Balke-Ware Test;

b) performance time during the running test;

c) the MBC tests;

d) resting, exercising and recovery measures associated with heart rate, R.Q., $O_2$ consumption and $CO_2$ production.

Since the effect of the experimental condition may reflect itself not only in a mean difference between the two groups but also in a variance difference, F tests to determine homogeneity of variance were computed for the data to be statistically evaluated (9:140). Tests of significance of the difference between the means were computed for correlated samples according to Ferguson (9:138,App.A). Statistical treatment of the data was undertaken for scores obtained for the

a) Balke-Ware Treadmill Tests,

b) Treadmill Running Test,

c) MBC Tests,

d) Resting Heart Rates.

Where data for subgroups $A_1$ (n = 5) and for $A_2$ (n = 5) were compared to that of groups B (n = 10) or C (n = 10), the subjects comprising the subgroups were statistically compared only with those subjects in groups B or C with whom they were originally equated.

Graphical Representations. Graphs were plotted for groups $A_1$, $A_2$, B and C for each of the three test periods as follows:

1. Graphs indicating the relationship during exercise between

(a) performance time and heart rate,

(b) performance time and R.Q.,

(c) performance time and $O_2$ consumption,

(d) performance time and $CO_2$ production.

2. Graphs indicating the relationship during a 5 minute recovery period between

(a) heart rate and recovery time,

(b) R.Q. and recovery time,

(c) $O_2$ consumption and recovery time,

(d) $CO_2$ production and recovery time.

3. Mean performances during the three testing periods for the 4 groups involved were plotted for the Balke-Ware tests, the running tests and the MBC tests.

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CHAPTER IV

RESULTS AND DISCUSSION

RESULTS

TREADMILL PERFORMANCE

(a) Balke-Ware Test. Experimental group A (16.7 mins.) and B (16.7 mins.), and control group C (16.6 mins.) were equated on the basis of initial performance times for the Balke-Ware test. Group B (circuit) exhibited the greatest improvement (Fig. 1; Tables IV, V), with a mean gain of 1.60 minutes after 5 weeks of training ($p < .05$). Group A (5BX) gained an average 0.9 minutes during the same training interval ($p < .10$). Control group C showed a mean loss of 0.70 minutes after 5 weeks, the greatest loss of 1.00 minutes occuring during the first 2.5 weeks. Neither loss was significant ($p > .20$). No statistically significant differences ($p \leq .05$) was found between groups A and B ($p > .50$) or between groups A and C ($p < .20$) on the final test (Table VI). Group B, however, showed a significant mean gain of 2.40 minutes over control ($p < .05$) on the final test performance.

When performance times of subgroups $A_1$ (16.5 mins.) and $A_2$ (16.8 mins.) were compared with those for groups B and C (Fig. 2; Tables V, VI) group $A_2$ provided the greatest increase during the 5 weeks of training of 1.70 minutes ($p < .05$). This increase was realized after the first 2.5 weeks of exer-

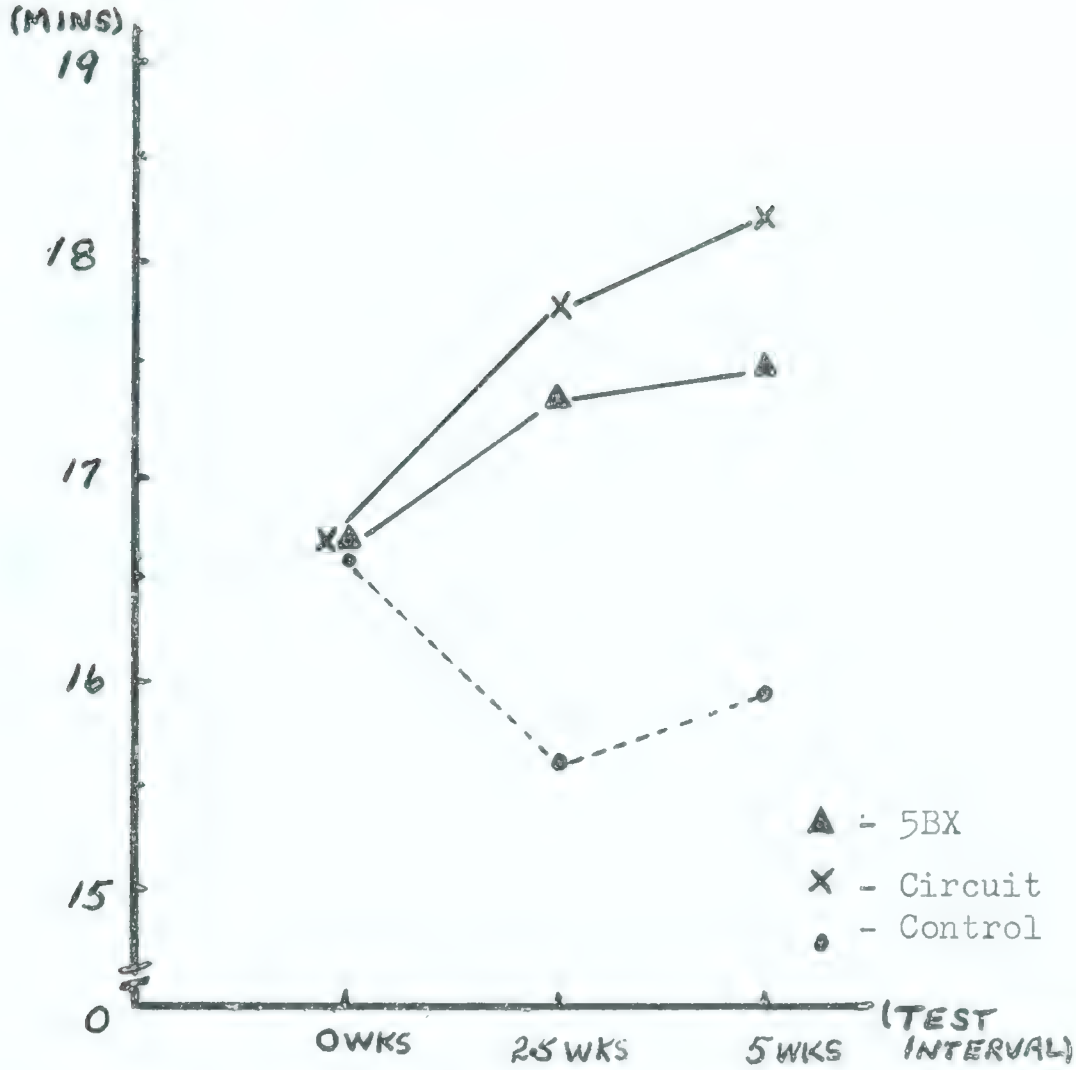


Figure 1. Mean Performance Times Balke-Ware Treadmill Test.

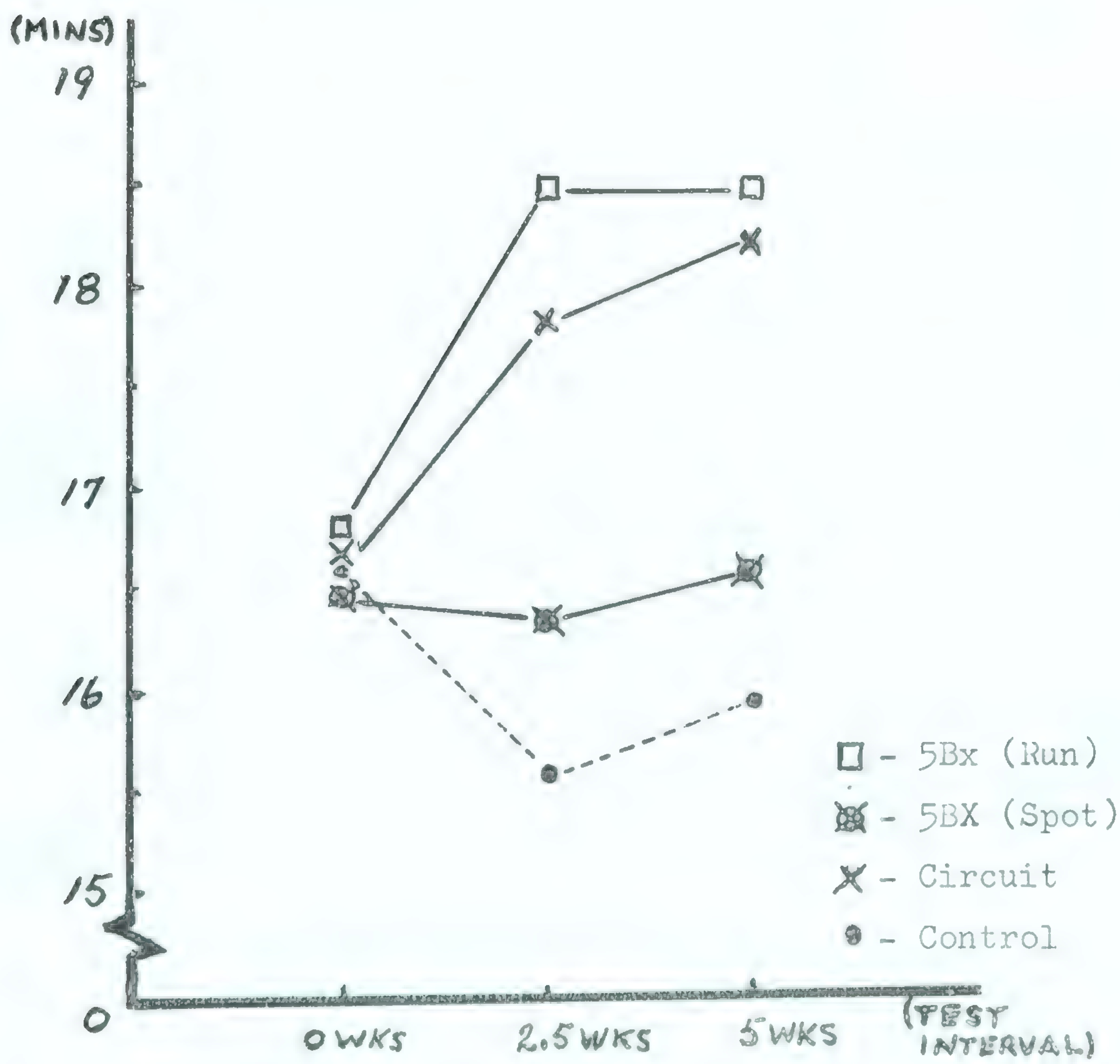


Figure 2. Mean Performance Times Balke-Ware Treadmill Test Group A Subdivided.

TABLE IV

MEAN PERFORMANCE TIMES (MINS.)

BALKE-WARE TREADMILL TEST

| GROUP | A MINS. SD. | $A_1$ MINS. SD. | $A_2$ MINS. SD. | B MINS. SD. | C MINS. SD. |
|---|---|---|---|---|---|
| TEST PD. | | | | | |
| 1 | 16.7±2.80 | 16.5± 3.34 | 16.8±2.54 | 16.7±3.25 | 16.6±2.43 |
| 2 | 17.4±2.81 | 16.3± 3.15 | 18.5±2.18 | 17.8±3.65 | 15.6±1.89 |
| 3 | 17.6±2.39 | 16.6± 1.85 | 18.5±1.34 | 18.3±3.44 | 15.9±1.77 |

TABLE V

INTRA-GROUP COMPARISON OF BALKE-WARE TREADMILL PERFORMANCE

BETWEEN INITIAL AND FINAL TEST SCORES

| GROUP | MEAN OF DIFFS. (MINS.) | ST. ERROR OF DIFFS. | t | p |
|---|---|---|---|---|
| A | 0.9 | 0.43 | 2.076 | <.10 |
| B | 1.6 | 0.61 | 2.551* | <.05 |
| C | 0.6 | 0.55 | 1.109 | >.20 |
| $A_1$ | 0.1 | 0.40 | 0.250 | >.50 |
| $A_2$ | 1.7 | 0.61 | 2.810* | <.05 |

*Sig. at .05 level.

cise and was maintained through the final half of the experimental period. Group $A_1$ gained 0.10 minutes for the same training period and experienced a loss of 0.20 minutes in performance time between the first and second test intervals. No statistically signigicant differences between the means ($p \leq .05$) was found between groups $A_1$ and $A_2$ on tests 2 and 3 ($p < .20$), $A_2$ and B on test 3 ($p > .50$) nor between groups $A_1$ and B on test 3 ($p < .20$). Significant gains were observed between group $A_2$ and control on tests 2 and 3 ($p < .01$) and in group $A_2$ between the initial and final testing periods ($p < .05$).

The test-retest reliability coefficient ($N = 30$) for the Balke-Ware treadmill test was .880 ($p < .01$).

(b) Treadmill Run To Exhaustion. 'F' tests for homogeneity of variance and 't' tests to determine any significant differences between the means on the initial exhaustion run scores (Tables XIX, XX App. A) provided evidence that no significant difference existed between the groups and that they were, in fact, drawn from the same population. On this basis the assumption has been advanced that groups A, B and C remained equated for this test.

Group B (Fig. 3; Tables VII, VIII) exhibited the largest mean gain (1.02 mins.) following the 5 weeks of training ($p < .01$). The mean increase of 55 seconds for group A was also significant ($p < .01$). No significant difference was

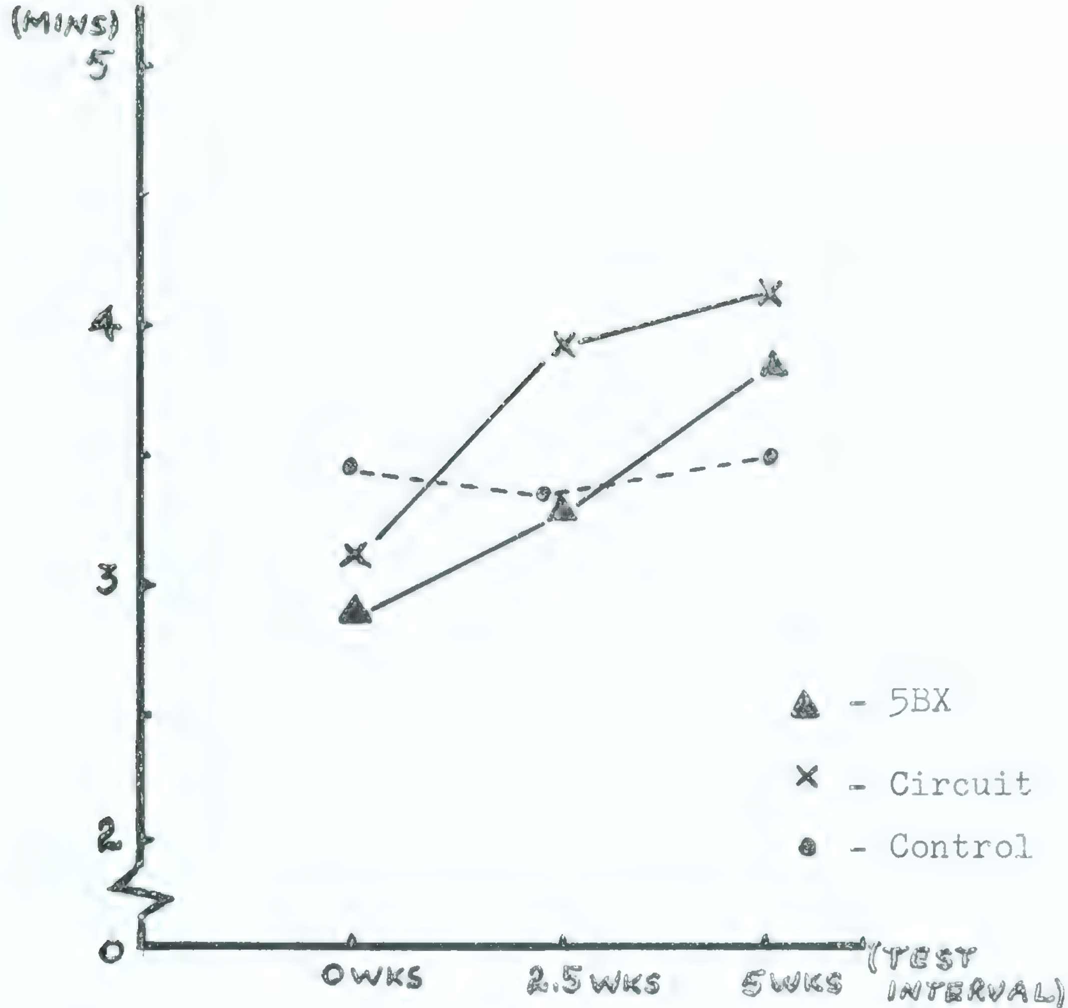


Figure 3. Mean Performance Times Treadmill Run To Exhaustion.

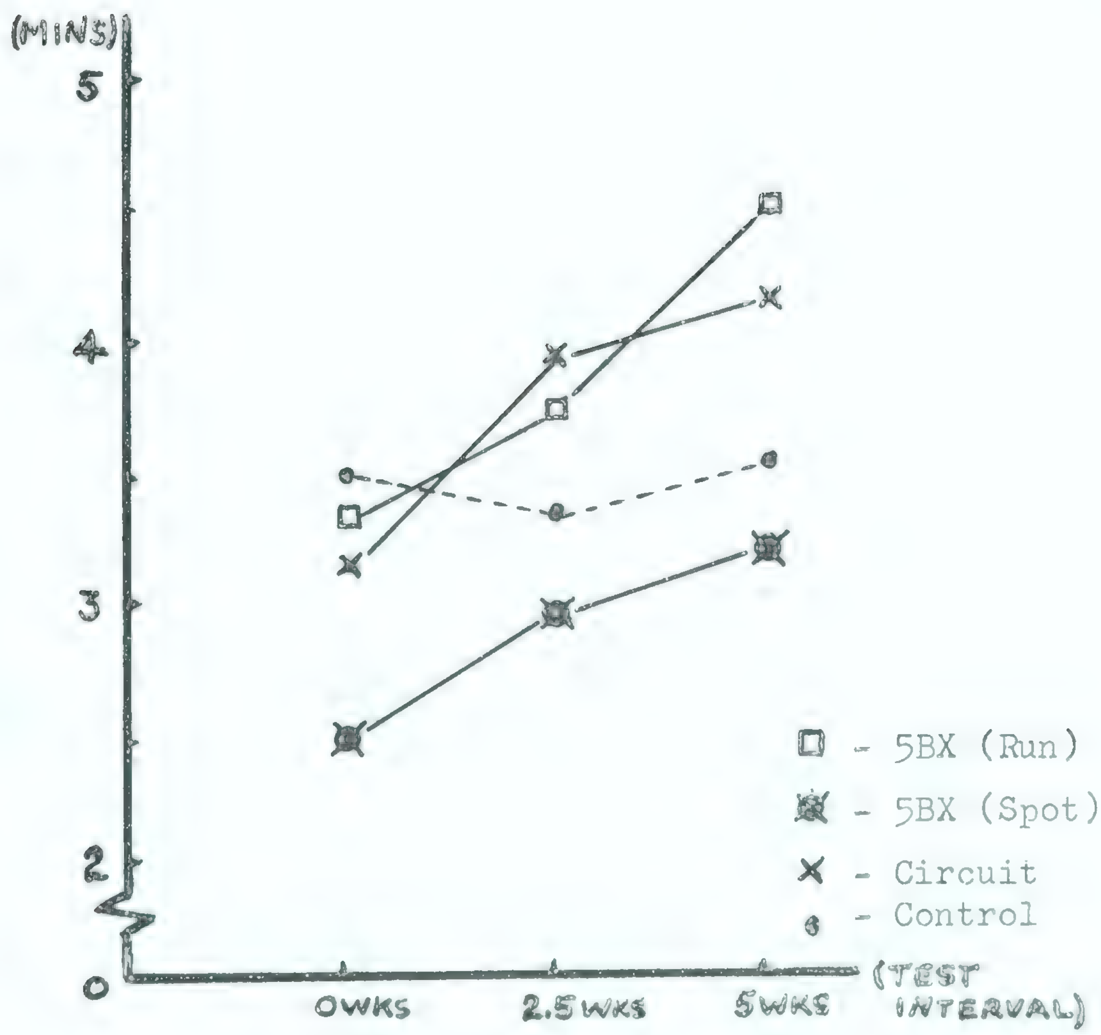


Figure 4. Mean Performance Times Treadmill Run To Exhaustion Group A Subdivided.

TABLE VI

INTER-GROUP COMPARISON OF BALKE-WARE TREADMILL PERFORMANCE

FINAL TEST SCORES

| GROUPS COMPARED | MEAN OF DIFFS. (MINS.) | ST. ERROR OF DIFFS. | t | p |
|---|---|---|---|---|
| A - B | 0.7 | 1.33 | 0.525 | >.50 |
| A - C | 1.6 | 0.91 | 1.759 | <.20 |
| B - C | 2.3 | 0.96 | 2.408* | <.05 |
| $A_1$ - $A_2$ | 1.9 | 1.14 | 1.673 | <.20 |
| $A_1$ - B | 1.1 | 0.58 | 1.900 | <.20 |
| $A_1$ - C | 0.6 | 0.93 | 0.647 | >.50 |
| $A_2$ - C | 2.6 | 0.37 | 7.096** | <.01 |

*Sig. at .05 level. **Sig. at .01 level.

TABLE VII

MEAN PERFORMANCE TIMES (MINS.)

TREADMILL RUN TO EXHAUSTION

| GROUP | A | | $A_1$ | | $A_2$ | | B | | C | |
|---|---|---|---|---|---|---|---|---|---|---|
| TEST PD. | MINS. | SD. | MINS. | SD. | MINS. | SD. | MINS. | SD. | MINS. | SD. |
| 1 | 2.94±0:36 | | 2.49±0:26 | | 3.38±0:23 | | 3.17±0:48 | | 3.43±0:55 | |
| 2 | 3.34±0:41 | | 2.91±0:35 | | 3.77±0:30 | | 3.96±0:48 | | 3.37±0:42 | |
| 3 | 3.86±0:55 | | 3.20±0:33 | | 4.52±0:42 | | 4.19±1:11 | | 3.52±0:46 | |

found between performance times of groups A and B ($p > .20$), A and C ($p > .50$) or B and C ($p < .10$) upon evaluating the final test scores (Table IX).

When subgroup $A_2$ was compared with groups B and C, the mean increase of 1.14 minutes in performance time by group $A_2$ provided the greatest gain ($p < .05$) by any of the experimental groups during the initial and final test intervals (Fig. 4; Tables VII, VIII).

For purposes of statistical intergroup comparisons involving subgroup $A_1$, differences in gains in performance time were considered for all groups. This was necessary since the mean score for the initial exhaustion run for group $A_1$ was lower ($p < .10$) than that of the other groups. Any statistical differences between the scores could thus be more accurately detected. Analysis of the final test scores indicated that subgroup $A_2$ was not statistically superior to $A_1$ ($p > .20$) in performance time gains. Subgroup $A_1$ showed a mean gain of 43 seconds over the 5 week training period ($p < .05$) but no statistical differences ($p \leq .05$) were revealed between $A_1$ and the other groups for the final test period.

The test-retest reliability coefficient for the treadmill run to exhaustion ($N = 10$) was .734 ($p < .02$).

(c) Maximum Breathing Capacity. Since 'F' ratios and 't' scores (Appendix A) determined from the initial test data

TABLE VIII

INTRA-GROUP COMPARISON OF TREADMILL RUN TO EXHAUSTION BETWEEN INITIAL AND FINAL TEST SCORES

| GROUP | MEAN OF DIFFS. (SECS.) | ST. ERROR OF DIFFS. | t | p |
|---|---|---|---|---|
| A | 55.4 | 13.14 | 4.216** | <.01 |
| B | 49.5 | 15.31 | 3.233* | <.02 |
| C | 9.2 | 10.78 | 0.853 | >.20 |
| $A_1$ | 42.4 | 12.33 | 3.439* | <.05 |
| $A_2$ | 68.4 | 23.24 | 2.943* | <.05 |

*Sig. at .05 level. **Sig. at .01 level.

TABLE IX

INTER-GROUP COMPARISON OF TREADMILL RUN TO EXHAUSTION FINAL TEST SCORES

| GROUPS COMPARED | MEAN OF DIFFS. (SECS.) | ST. ERROR OF DIFFS. | t | p |
|---|---|---|---|---|
| A - B | 23.0 | 32.54 | 0.707 | >.20 |
| A - C | 17.3 | 30.18 | 0.573 | >.50 |
| B - C | 40.3 | 22.25 | 1.811 | <.10 |
| $A_1$ - $A_2$ | 27.4 | 26.11 | 1.049 | >.20 |
| $A_1$ - B | 12.2 | 6.19 | 1.971 | <.20 |
| $A_1$ - C | 11.4 | 23.47 | 0.486 | >.50 |
| $A_2$ - C | 70.0 | 35.00 | 2.000 | <.20 |

indicated that the 3 groups were homogeneous in variance ($p > .10$) and revealed no significant difference between the means ($p > .50$), the assumption that the groups A, B and C remained equated for this test was also advanced.

Following the initial test, the mean MBC scores for all 3 groups were very closely matched (Fig. 5, Table X), varying only by 3.9 l/min. After 2.5 weeks of training the resting MBC's showed little change and were only slightly lower on the second test determinations than on the first, for all 3 groups. The inter and intra-group variation between first and second test scores was less than 5 l/min. Large gains were observed over the last half of the experimental period for group B with a mean increase of 23.7 l/min. between tests 2 and 3. Group A improved over their second test performance by 7.6 l/min. Control group C also exhibited a mean gain of 11 l/min. during this period. There was no statistically significant difference ($p \leq .05$) between the groups on test 3 (Table XI). The gain in performance between initial and final test periods by group B was significant at the .02 level of confidence. Group A ($p > .20$) and Group C ($p > .50$) showed no significant gains after 5 weeks of training (Table XII).

An analysis of the data for the subgroups $A_1$ and $A_2$ (Fig. 6; Tables X, XII), revealed that group $A_2$ experienced no change in MBC after 5 weeks of training and returned a

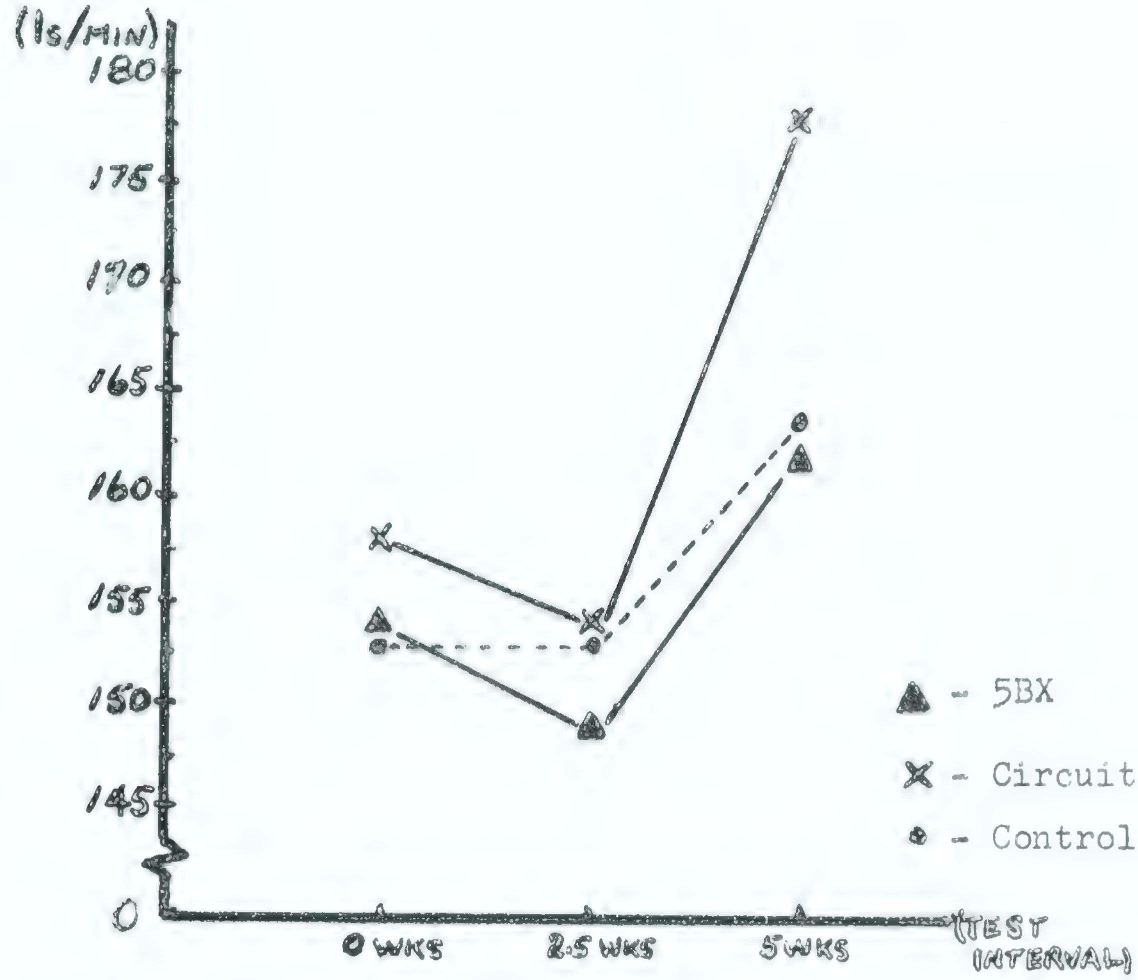


Figure 5. Mean Resting Maximum Breathing Capacities

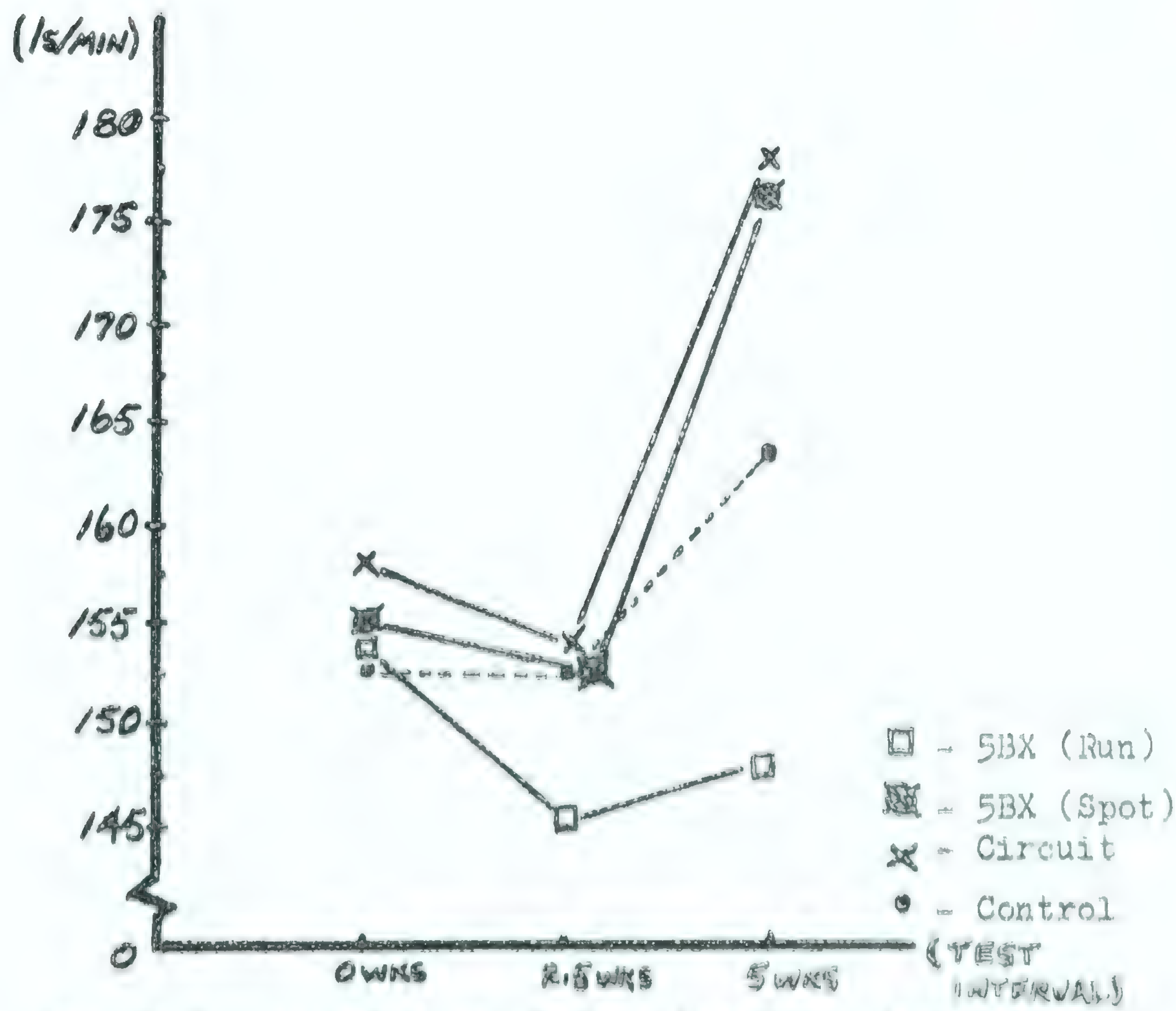


Figure 6. Mean Resting Maximum Breathing Capacities
Group A Subdivided.

mean performance for the final test of 6.5 l/min. lower than their initial score. In contrast, group $A_1$ closely paralleled the trend established by groups B and C during the 3 testing intervals, with a mean gain of 21.7 l/min. ($p > .20$).

TABLE X

RESTING MAXIMUM BREATHING CAPACITIES AND

MEAN RATES OF BREATHING (BREATHS/MIN.)

| GROUP | A | $A_1$ | $A_2$ | B | C |
|---|---|---|---|---|---|
| TEST 1 | | | 0 WEEKS OF TRAINING | | |
| L/MIN. | 154.7 | 155.0 | 154.3 | 157.7 | 153.8 |
| SD | ±28.1 | ±36.7 | ±20.8 | ±28.6 | ±28.0 |
| BR/MIN. | 98 | 113 | 83 | 103 | 91 |
| TEST 2 | | | 2.5 WEEKS OF TRAINING | | |
| L/MIN. | 149.4 | 152.9 | 145.8 | 154.8 | 153.7 |
| SD | ±33.4 | ±45.1 | ±21.0 | ±20.6 | ±22.8 |
| BR/MIN. | 93 | 102 | 84 | 90 | 101 |
| TEST 3 | | | 5 WEEKS OF TRAINING | | |
| L/MIN. | 162.3 | 176.7 | 147.8 | 178.5 | 164.8 |
| SD | ±36.6 | ±47.0 | ±16.8 | ±16.9 | ±29.7 |
| BR/MIN. | 89 | 84 | 94 | 92 | 88 |

TABLE XI

INTER-GROUP COMPARISON OF RESTING MAXIMUM BREATHING CAPACITIES FINAL TEST SCORES

| GROUPS COMPARED | MEAN OF DIFFS. (L/MIN.) | ST. ERROR OF DIFFS. | t | p |
|---|---|---|---|---|
| A - B | 16.26 | 13.49 | 1.205 | >.20 |
| A - C | 2.07 | 16.51 | 0.125 | >.50 |
| B - C | 19.65 | 11.89 | 1.653 | <.20 |
| $A_1$ - $A_2$ | 28.90 | 14.78 | 1.955 | <.20 |
| $A_1$ - C | 32.30 | 24.51 | 1.318 | >.20 |
| $A_2$ - B | 26.10 | 13.79 | 1.893 | <.20 |
| $A_2$ - C | 37.40 | 14.98 | 2.497 | <.10 |

TABLE XII

INTRA-GROUP COMPARISON OF RESTING MAXIMUM BREATHING CAPACITIES BETWEEN INITIAL AND FINAL TEST SCORES

| GROUP | MEAN OF DIFFS. (L/MIN.) | ST. ERROR OF DIFFS. | t | p |
|---|---|---|---|---|
| A | 8.31 | 9.21 | 0.902 | >.20 |
| B | 20.89 | 6.96 | 3.001* | <.02 |
| C | 3.54 | 10.04 | 0.353 | >.50 |
| $A_1$ | 21.72 | 14.51 | 1.480 | >.20 |
| $A_2$ | 6.50 | 8.79 | 0.739 | >.50 |

*Sig. at .05 level.

DISCUSSION

(a) Treadmill Performance. The initial mean performance times of 16.6 - 16.7 minutes for the Balke-Ware test would indicate that the subjects participating in this study were above average in cardio-respiratory fitness (1:683). No subject participated in any form of regular or systematic activity for at least 1 month prior to the study, however, the participants were physically active individuals. Balke and Ware (1:682) suggest an arbitrary average performance time of approximately 15 minutes for the, ". . . intermittently active individual" (1:682). Alexander et al (2) found a mean initial performance time of 14.6 minutes for untrained young medical students. When consideration is given to the fact that the experimental groups began at a level 1 - 2 minutes above these reported means for untrained subjects, the mean gains of 1.70 ($A_2$), 1.60 (B) and 0.90 (A) minutes compare most favorably with the gains of 2.5 minutes found by Balke (3:5), and 3 minutes by Alexander and associates (2) over a period of training of comparable duration. Balke (3:5) also observed a loss of 1.5 minutes in performance time for a group of 7 cadets deconditioned by complete inactivity involving 4 weeks of bed rest. The control group in the present study showed a loss of 1.00 minute during the first 2.5 weeks of the experimental period, the mean performance time falling toward the previously suggested average for un-

trained individuals. While the control group was not as severely restricted in their activity as was the case in Balke's study, relative inactivity was a requirement of this group. The further inactivity induced by study requirements preparatory to mid-term examinations also undoubtedly contributed to the lower scores of the controls on test 2. With resumption of some sporadic activity during the final 2.5 weeks of the study the control group showed a negligible improvement of 0.3 minutes on the final test.

In order that the effects of the exercise programs could be studied under conditions requiring prolonged maximal work, an all-out treadmill test was selected as the standardized measure of cardio-respiratory improvement. Since the Balke-Ware test is terminated at approximately the point where a transition from aerobic to anaerobic work occurs, it cannot be expected that this test which is primarily concerned with the capacity of the aerobic processes of the individual, could provide accurate information concerning the capacity of the individual for anaerobic work. The speed of 7 mph and 8.6% grade was selected based on the recommendations of Consolazio _et al_ (4:343), Cureton (5:314) and Taylor _et al_ (6:75) that this is the slowest speed which will force all subjects to maintain a running stride and still be slow enough to insure that a wide range of capacity could be tested satisfactorily.

Wolf (7) studied 102 subjects varying in their level of fitness on all-out treadmill performance at 7 mph and 8.6% grade and found a range of 1.48 - 16.13 minutes with a mean performance time of 5.93 minutes. Similar consideration of the data for this study indicates a mean initial performance time of 3.18 minutes ±0.29 and a range of 2.18 - 7.11 minutes. More extensive comparisons are not possible since the available data is very limited.

Group B showed the greatest gains during the first 2.5 weeks of exercise maintaining the trend observed for the Balke-Ware test. Group A, however, produced its greatest gains during the second half of the experimental period. When group A was studied in terms of subgroups $A_1$ and $A_2$ it was apparent that this effect was due to the slower initial progress of group $A_2$, group $A_1$ following the trend previously established. The lower initial gains by $A_2$ would seem to suggest that the cardio-respiratory adjustments necessary to efficiently perform the basic 5BX exercises and to run the 1 mile course were realized more slowly then for the other groups. These limitations would probably be dependent upon the acquisition of a sufficient degree of skill to perform these activities efficiently. Concomitant with an increased level of skill are the compensatory cardio-respiratory adaptations manifested by the more rapid gains in treadmill performance time during the last 2.5 weeks of exercise.

Generally, the trends are in agreement with Alexander *et al* (2) in that the greatest gains were observed during the initial 2.5 weeks of training with a slower steady rise (revealing a tendency of the performance times to plateau) over the final experimental period. Such a trend is not unreasonable. With the regularly increased stress placed on the cardio-respiratory system beyond the customary daily expectations, initial adaptations are quickly made. Knehr *et al* observed that:

> Any regime systematically followed will have its most striking results following a few weeks of training; after the first rapid gains, hard diligent work is required if a continued improvement is to be secured (8:148).

The rate of improvement is dependent upon the individual's initial state of fitness and upon the intensity of participation in the training program. Mechanical efficiency, technique or skill must also be regarded as a factor in determining physical fitness as well (9:316). Van Huss and associates (10:81) observed that: "Early learning involves some rapid periods of improvement followed by leveling off periods," where the acquisition of motor skills is concerned. It is not unlikely that this factor may be reflected to some degree in the exercise programs as revealed by treadmill performance times.

Since the respiratory and circulatory systems play a dominating role in aerobic work especially where large muscle

groups are engaged (9:307) it is to be expected that relatively high positive relationship would be obtained between performance times by the same individual on 2 different types of treadmill tests provided the tests can be performed aerobically. Where the work is still aerobic for the exhaustion run a relatively high relationship between running at 7 mph at 8.6% and walking the Balke test should hold; i.e., a person performing well on the Balke test should perform well on the exhaustion run as long as the cardio-respiratory system is the limiting factor. The exhaustion run, however, quickly drives the subject into an anaerobic state. The limiting factor for performance time is now the tolerance of the individual's muscle cells to the anaerobic metabolites (9:307). In addition, psychological factors will play an important part; a factor of little concern in the Balke-Ware test since the terminal point is decided by a physiological function. The lower initial exhaustion run scores for group $A_1$ do not seem so illogical in the light of this reasoning.

While admittedly motivation may cause variation in the exhaustion endpoint, this investigator, in agreement with Morse _et al_ (11:689) and Taylor _et al_ (6:33), is satisfied that in the majority of cases the stopping of the running test coincided with unquestionable signs of physiological distress reflected by the color of the face, ears and lips, the rate and depth of ventilation, profuse perspiration and

difficulty in maintaining the speed requirements of the treadmill. Furthermore, the subjects had no simple way of knowing the time during their runs and, therefore, could make no deliberate plan to repeat past performances. More of a major concern as a limiting factor to performance for this test was the weakness of the lower extremities. Complaints of pain and cramping of the legs were also noted by Slonim *et al* (12:403).

(b) Maximal Breathing Capacity. An important element in any battery of tests designed to determine the functional status of any body system is a quantitative measure of the capacity of that system to carry on its specific function (13:677). The Maximum Breathing Capacity test would appear to be more than a simple measurement of lung volume. Excessive ventilation in itself serves no useful purpose since the transportation of $O_2$ to the tissues is limited by the inability of the circulatory system to take up and deliver it to the cells (14:281), (15:154), (16:173). However, the ability of an individual to breath at a high velocity depends on several important factors including muscular force, patency of the airways and pulmonary elasticity and distensibility (17:362). Therefore, the supported observation by Knowles (18:19) that the MBC test is, ". . . the only test which evaluates the over-all, integrated function of the ventilatory apparatus," would seem to justify its inclusion

as a test of respiratory fitness (19:269), (20:103), (21:82), (22:314), (23:492), (24:211). The MBC test then, is a quantitative measure of the ability of the respiratory system to carry out its specific function, that is to provide an alternative current of air in and out of the lungs. It is used to estimate the efficiency of the various mechanical factors concerned in ventilation. In effect, it is an exaggerated measure of the number of liters of air an individual would breathe during the most strenuous exercise. It is similar to other tests of organic function in that the ventilatory mechanism is overloaded and its response to the overload is measured (25:331). Gray (13:679) points out that his test-retest reliability coefficient of .80 indicates that,

> . . . the variation in ventilatory capacity between different individuals is considerably greater than the variation encountered within the same individual when the test is repeated.

The procedure, therefore, has appreciable power to distinguish between different individuals.

One of the purposes of this study, then, was to provide some information regarding the effect of the 2 exercise programs on the respiratory mechanism and, using the MBC test as a measure, to determine any resulting changes in respiratory fitness attributable to exercise.

The methods, procedures and findings of previous investigators for subjects in the age range 15 - 30 have been

summarized and presented (Table III:38). The techniques employed in this study were those purported to provide the most reliable and consistent measurements. Because of differences in methods employed and differences in obtaining standardized voluntary effort in different subjects, there is a wide range of normal values for MBC's. Knowles (18:22) observed that standard deviations of mean values obtained ranged from ±15.9 to ±30.9 l/min. The present study reveals standard deviations for mean values ranging from ±16.8 to ±48.0 l/min. Because of these large deviations a healthy person may vary by 25 - 35% of mean group values (26:130), consequently, changes in the MBC must be large to be significant (26:130), (17:367), (18:22). Knowles (18:22) advises that the usual practice is to regard ±20% of the normal predicted value as the normal range.

Different authors have quoted normal mean values for MBC's for a wide range of subjects, varying in their state of fitness, ranging from 100 - 190 l/min. breathing air (Table III:38). The initial and final mean values, determined by the present study, of 153.8 - 157.7 l/min. and 162.3 - 178.5 l/min. compare most favorably with the figures reported for normal highly motivated, active males in the untrained and trained states. Valid comparisons with published results are difficult, however, since procedures for administering the test are not standardized. Until standardization

of procedures for determining MBC's is realized, it appears that, ". . . each laboratory must calibrate its own equipment and establish its own norms" (26:129).

Optimum breathing rates for maximum performance and the methods by which they may be obtained are also not uniform nor standardized. Gray et al (13:677), Sheppard (27:6), Knowles (18:21) and Rossier (28:135) highly recommend that the subject select his own depth and rate of breathing since, ". . . as a rule maximum ventilation can be attained only by voluntary effort" (26:129). The use of a metronome as a regulatory device was not employed because, ". . . such a diversion of concentration produced smaller and more variable ventilatory volumes" (27:3).

Maximum movement of air was found to occur near 90 breaths/min. for this study (Table X). This confirms the observations advanced by Sheppard (27), Bernstein et al (29), and Olgilvie et al (30). While no attempt was made to regulate breathing, most subjects tended to breath at the rate most conducive to moving the maximum volume of air once they became familiar with the apparatus and techniques involved. The rapid and shallow pattern of breathing proved inferior to the slower and deeper pattern. In agreement with D'Silva and Mendel (25:325):

> Not only was there a wide variation in the rates chosen by different subjects but the same subjects chose different rates on successive attempts.

Breathing rates for this study ranged from a mean value of 83 - 113 breaths/min. on test 1, to 84 - 102 on test 2, and 84 - 94 on test 3 (Table X). It is, therefore, the opinion of the present investigator that some method be employed during the MBC test to control this variability in breathing. Some suitable auditory or visual signal for guiding the rate of breathing set at an empirically determined and standardized optimum frequency must be used. Rigid adherence to the stimulus rhythm would not be necessary in consideration of individual differences and in order to avoid inferior performance due to any diversion of attention.

The learning factor, motivation and degree of cooperation of the subject, in addition to the rate and depth of breathing have a decided influence on the MBC test. Learning would seem to be still taking place during the third test period since breathing rates continued to decrease concomitant with an increase in performance as shown by the gains on test 3 by the control group. A very definite knack is required to produce a good MBC. In agreement with Gray et al (13:677) very little variation occurred between successive trials on the same day. Few data are available, however, concerning the variability in MBC performance for healthy individuals from day to day or over a period of weeks. Large variations were observed in the control group over 2.5 week intervals. It is anticipated then that the learning factor

contributed in some degree to both the gains and losses in MBC during the testing intervals.

The fact that any gains were not realized until the latter half of the experimental period would suggest that if systematic exercise promotes any changes in the resting MBC it must be regular and at a rather intense level. While final test gains were considerable for groups $A_1$ and B, and statistically significant for B, the mean gains were not in excess of the 20% increase required by Knowles (18:22) to be physiologically significant. Considering (1) the same technician administered all tests using identical procedures, (2) the time, day and place of testing was the same during each test period for each subject, (3) the apparatus employed was regularly checked to detect mechanical malfunction, (4) instructions were simple, standard and clearly understood, (5) that group $A_2$ was required to run a timed 1 mile/day 5 days a week for 5 weeks in addition to the other 4 exercises thereby placing as much, if not more, stress on the respiratory mechanism than any other group, the failure of $A_2$ to show improvement may appear to be unusual. It is possible that the results are aberrant because of the small number, yet the pattern from group to group appears to be consistent. Sizeable variations in the score of a single individual as the result of a temporary respiratory infection, for instance, can significantly affect the mean value for the

group. Another possible factor is concerned with adaptations to distance running. A runner tends to develop a regular pattern of breathing over the longer distances. During a period of training it is conceivable that this pattern becomes rather definitely established. When required to perform an MBC test, the subject could possible experience difficulty in breaking a pattern of breathing that has become fairly automatic under conditions of stress and then suddenly attempt to adjust to a new pattern in the space of 15 seconds. A maximum performance under such circumstances would seem unlikely. What seems more likely is that the MBC is not a valid test of adaptation to exercise. It is possible that with increased ventilatory efficiency produced by the training program so little stress was placed on the respiratory mechanism of group $A_2$ that no change was induced over the 5 week period.

The MBC test, therefore, can give some information regarding the breathing mechanism of healthy young males but since it is affected by so many factors, test results must be viewed with reservation and cautiously interpreted. In agreement with Comroe (17:368) until these factors can be controlled, techniques and procedures standardized and norms established, the test loses much of its effectiveness as a measure of respiratory fitness for healthy active individuals. Considering these limitations then, the evidence compiled for this study suggests that gains in the resting MBC realized

after 5 weeks of training may be partly attributed to the exercise programs and partly to a learning factor. The degree that each factor may contribute to these gains is a matter for further investigation.

## PHYSIOLOGICAL FUNCTIONS

(a) Heart Rate. Since the cardio-respiratory system is intimately concerned with physical activity, its response to exercise would seem to be the best measure of an individual's physical fitness. Ideally a test of cardio-respiratory efficiency would be one from which all psychological factors were eliminated (3:1). This is frequently difficult to control, consequently where psychological influences may affect the accuracy of the information derived from physiological measurements and hence the performance of the subject, interpretation of the resulting data must provide for these factors. However, the simple measurement of heart rate can provide some valuable indication of the adaptability of the cardiovascular system to variations in physical performance (3:1).

Data for two sets of resting heart rates were recorded, one set previous to each of the treadmill tests. The subjects reported to the lab at least 15 minutes prior to their test and were required to sit quietly until that time. An additional 2 minutes of quiet standing was implemented after all measurement apparatus was attached to permit the subject

to adjust to the equipment and to the new body position. It would be expected then that the resting heart rates prior to each test would be very similar especially since the treadmill performances were conducted only two days apart. This observation is generally supported by the data (Table XIII) with the exception of the slightly higher resting values previous to the initial exhaustion run. The difference here is probably psychological due to the anticipation and consequent apprehension associated with the concept of running to exhaustion. The resting heart rates of the control group were generally 10 - 15 beats/min. higher on all tests than those for groups A and B. Lower resting heart rates were observed for all groups following the 5 week experimental period. While group C also showed lowered resting heart rates on test 3, these values remained considerably higher than those for groups A and B. In the absence of any

TABLE XIII

MEAN RESTING HEART RATES

| GROUP | BALKE-WARE TEST | | | EXHAUSTION RUN | | |
|---|---|---|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ | $T_1$ | $T_2$ | $T_3$ |
| A | 78 | 77 | 76 | 81 | 73 | 72 |
| B | 81 | 78 | 76 | 82 | 76 | 72 |
| C | 95 | 90 | 88 | 92 | 89 | 86 |
| $A_1$ | 79 | 77 | 81 | 83 | 75 | 74 |
| $A_2$ | 76 | 78 | 71 | 79 | 71 | 71 |

$T_1$: 0 Weeks $T_2$: 2.5 Weeks $T_3$: 5 Weeks

strenuous activity the reduced resting values for group C may be attributed to a lessening of the influence of psychological factors commensurate with an increased familiarization of the subjects with the laboratory personnel and the nature and demands of the tests. This is in agreement with Cotton's observations (31:42). The degree to which this factor contributed to the lowered resting heart rates of the experimental groups is not known. Subgroup $A_2$ tended to exhibit lower mean resting values than did subgroup $A_1$.

The only statistically significant difference between initial and final resting heart rates was that for group A, but only prior to the exhaustion run (Tables XIV, XV). Considering the previous discussion it is unlikely that this significance can be entirely attributed to the effects of the exercise program. No statistical significance was found between the means of any of the groups on test 3 (Tables XVI, XVII).

It is widely reported in the literature that individuals in good physical condition show a smaller increment in heart rate during a given work load than do non-fit individuals (Chap. II, p. 19). Observations during the course of the 5 week experimental program do not entirely support these findings. During the Balke-Ware test little distinction could be made between mean exercise heart rates for the 3 groups on test 1 (Fig. 7; Table XXII App.C). Group A's

TABLE XIV

INTRA-GROUP COMPARISON OF DIFFERENCES IN RESTING HEART RATES RECORDED PRIOR TO BALKE-WARE TREADMILL TEST BETWEEN INITIAL AND FINAL TEST SCORES

| GROUP | MEAN OF DIFFS. (BTS/MIN.) | ST. ERROR OF DIFFS. | t | p |
|---|---|---|---|---|
| A | 1.6 | 2.38 | 0.672 | >.50 |
| B | 5.5 | 3.78 | 1.453 | <.20 |
| C | 6.8 | 7.29 | 0.933 | >.20 |
| $A_1$ | 1.6 | 3.23 | 0.495 | >.50 |
| $A_2$ | 4.8 | 3.15 | 1.524 | >.20 |

TABLE XV

INTRA-GROUP COMPARISON OF DIFFERENCES IN RESTING HEART RATES RECORDED PRIOR TO TREADMILL RUN TO EXHAUSTION BETWEEN INITIAL AND FINAL TEST SCORES

| GROUP | MEAN OF DIFFS. (BTS/MIN.) | ST. ERROR OF DIFFS. | t | p |
|---|---|---|---|---|
| A | 7.9 | 1.85 | 4.263** | <.01 |
| B | 5.5 | 4.02 | 1.369 | >.20 |
| C | 6.2 | 4.07 | 1.524 | <.20 |
| $A_1$ | 9.4 | 2.87 | 3.271* | <.05 |
| $A_2$ | 6.4 | 2.46 | 2.600 | <.10 |

*Sig. at .05 level. **Sig. at .01 level.

heart rate tended to be lower prior to the 10th minute of exercise then closely followed the trend of the mean values established by groups B and C. During the first minute of exercise, heart rates accelerated rapidly, especially that of group B, then dropped in the second minute as cardiovascular adaptations were quickly made to accommodate to the increased activity. A metabolic steady state cannot be expected at any time during this test because of the gradually increased work load. This fact is reflected in the slow upward drift of the exercise heart rate curve. After 5 weeks of training the mean exercise heart rates for the 3 groups were virtually identical up to the 10th minute of activity (Fig. 8; Table XXIV App.C). Two changes occurred on test 3 during the time interval 0 - 9 minutes. (1) Group B's mean heart rate was reduced by some 19 beats/min. in the first minute of exercise. Such a reduction in heart rate is a characteristic of the effects of training according to Elbel and Holmer (32:367). (2) Group A's mean heart rate was slightly higher for this entire interval. The close relationship between the groups during the initial 10 minute work period of test 3 is not unusual since the work intensity was light and easily accommodated by all individuals. After the first 10 minutes for test 3, however, a clearly defined separation between the mean heart rates for the exercise groups A and B from that of the control group was

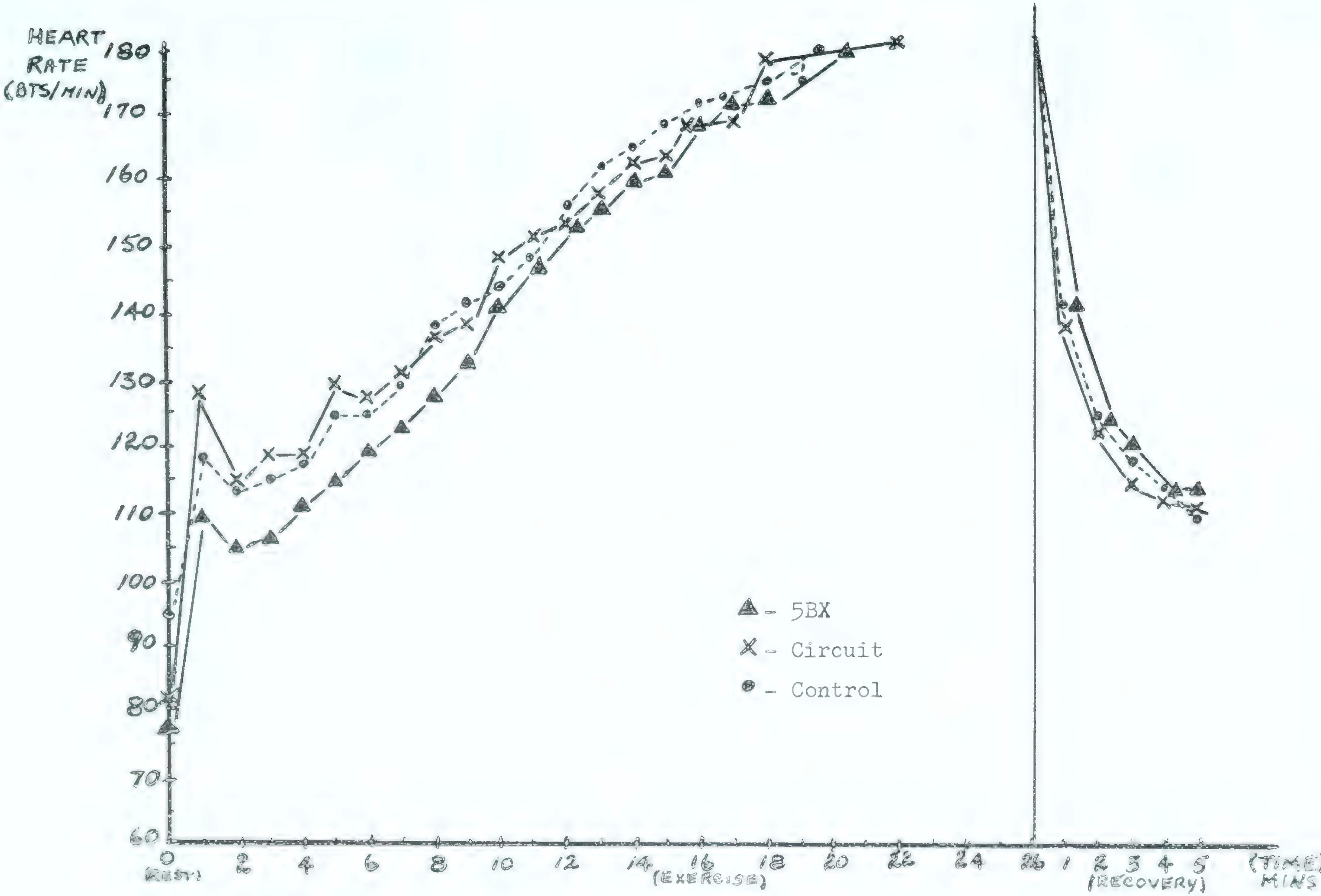


Figure 7. Mean Resting, Exercise and Recovery Heart Rates For Initial Test Period Balke-Ware Treadmill Test.

TABLE XVI

INTER-GROUP COMPARISON OF DIFFERENCES IN RESTING HEART RATES RECORDED PRIOR TO TREADMILL RUN TO EXHAUSTION FINAL TEST SCORES

| GROUPS COMPARED | MEAN OF DIFFS.(BTS/MIN.) | ST. ERROR OF DIFFS. | t | p |
|---|---|---|---|---|
| A - B | 4.2 | 3.26 | 1.287 | >.20 |
| A - C | 5.1 | 5.57 | 0.916 | >.20 |
| B - C | 9.3 | 6.19 | 1.502 | <.20 |
| $A_1$ - $A_2$ | 1.2 | 5.87 | 0.204 | >.50 |

TABLE XVII

INTER-GROUP COMPARISON OF DIFFERENCES IN RESTING HEART RATES RECORDED PRIOR TO BALKE-WARE TREADMILL TEST FINAL TEST SCORES

| GROUPS COMPARED | MEAN OF DIFFS.(BTS/MIN.) | ST. ERROR OF DIFFS. | t | p |
|---|---|---|---|---|
| A - B | 0.6 | 2.57 | 0.233 | >.50 |
| A - C | 11.1 | 8.76 | 1.267 | >.20 |
| B - C | 12.3 | 8.31 | 1.480 | <.20 |
| $A_1$ - $A_2$ | 9.6 | 9.94 | 0.966 | >.20 |

observed. Mean values for group B were relatively unchanged after 5 weeks of training. Groups A and C tended to show higher exercise heart rates for test 3 than for test 1 (Figs. 17, 19, 21 App.C). Subgroup $A_1$ showed consistently higher exercise heart rates during the final test. $A_2$ exhibited higher exercise heart rates at the lower levels of work during the final Balke-Ware test with little change observed after 12 minutes (Fig. 23, App.C).

The same general trend for exercise heart rates was noted during the exhaustion run. Following a rapid initial rise to approximately 160 beats/min. the 3 groups exhibited a tendency to plateau, as observed by Taylor (33:29), after the first minute of exercise (Fig. 9; Table XXV, App.C). No distinction between the mean exercise heart rates of the 3 groups was apparent during the initial exhaustion run. After 5 weeks of training, the exercise groups showed lower mean exercise heart rates while those of the control group remained unchanged (Fig. 10; Table XXVII and Figs. 18, 20, 22, 24 App. C). Subgroups $A_1$ and $A_2$ both exhibited lower exercise heart rates during the final exhaustion run.

While inter-group variations in the mean exercise heart rates were not large, the generally unchanged or lower values for groups A and B after 5 weeks of training accompanied by increased treadmill performance times would seem to imply that a more powerful and efficient heart had developed resulting in

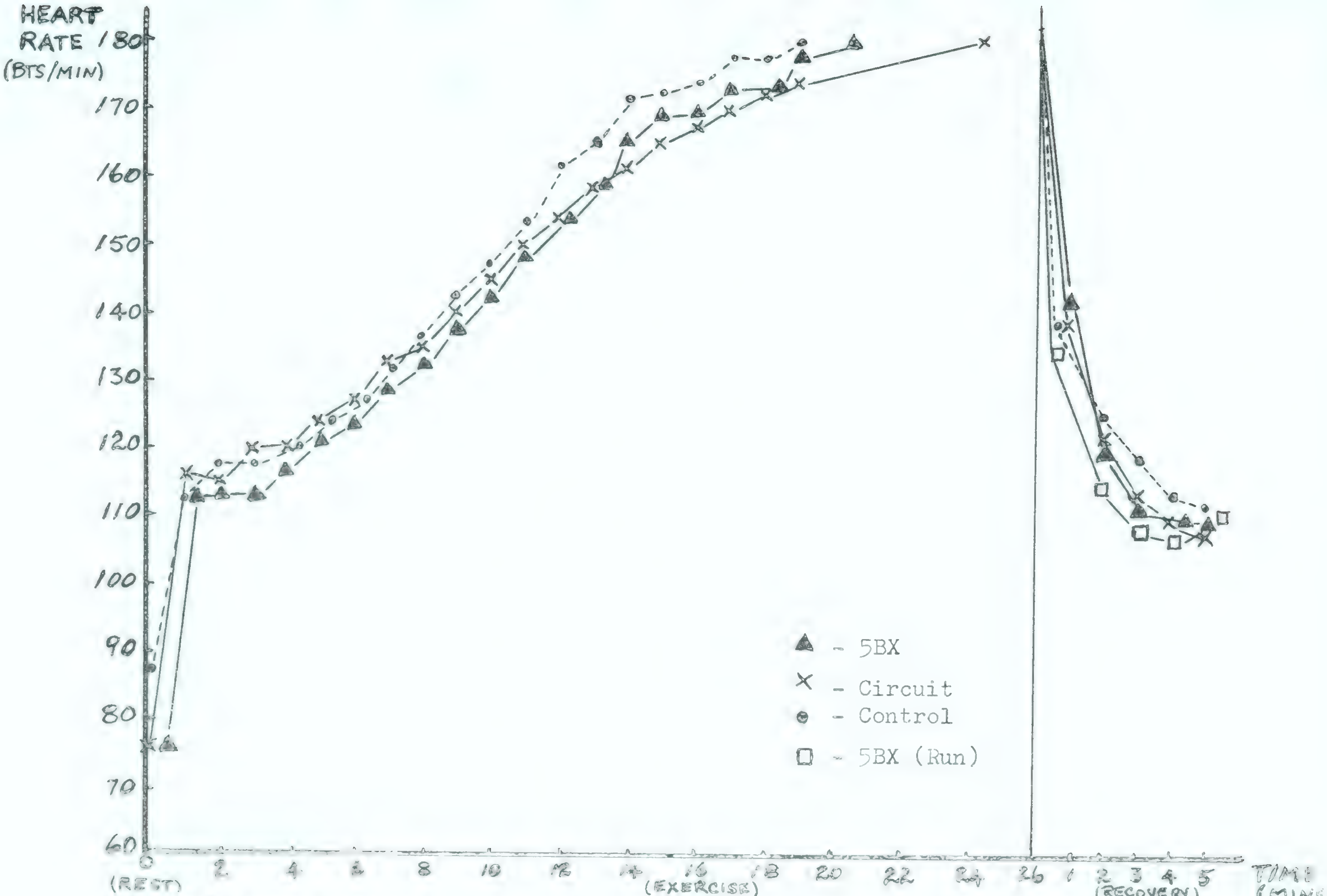


Figure 2. Mean Resting, Exercise and Recovery Heart Rates For Final Test Period Balke-Ware Treadmill Test.

a greater stroke volume. This observation would tend to support the findings of Chapman _et al_ (34:1212) and Henry (35:28).

During the Balke-Ware tests each subject was able to perform for at least 10 minutes. The same is true for the exhaustion runs up to 2 minutes. If the tests were terminated at this point statistical analysis of recovery heart rates would be meaningful and inter-group comparisons more justified. During the Balke-Ware tests, however, variations in performance time beyond 10 minutes were great, consequently, equally great variations occurred in the amount of work done by each individual as he reached the pulse rates of 165, 175 and 180 where physiological measurements were taken. The same observation is generally true for the exhaustion runs. All subjects did not terminate their performance after accomplishing an equal amount of work. It is, therefore, difficult to meaningly compare the recovery heart rates for the groups. General trends, however, can be observed and viewed with this reservation.

Following the initial Balke-Ware tests, mean recovery heart rates tended to fall rapidly from the terminal 180 beats/min. to near 140 during the first minute and to approximately 125 after 2 minutes (Fig. 7; Table XXII App.C). Recovery during the 3rd - 5th minutes was much more gradual, the recovery values tending to plateau some 30 beats/minute

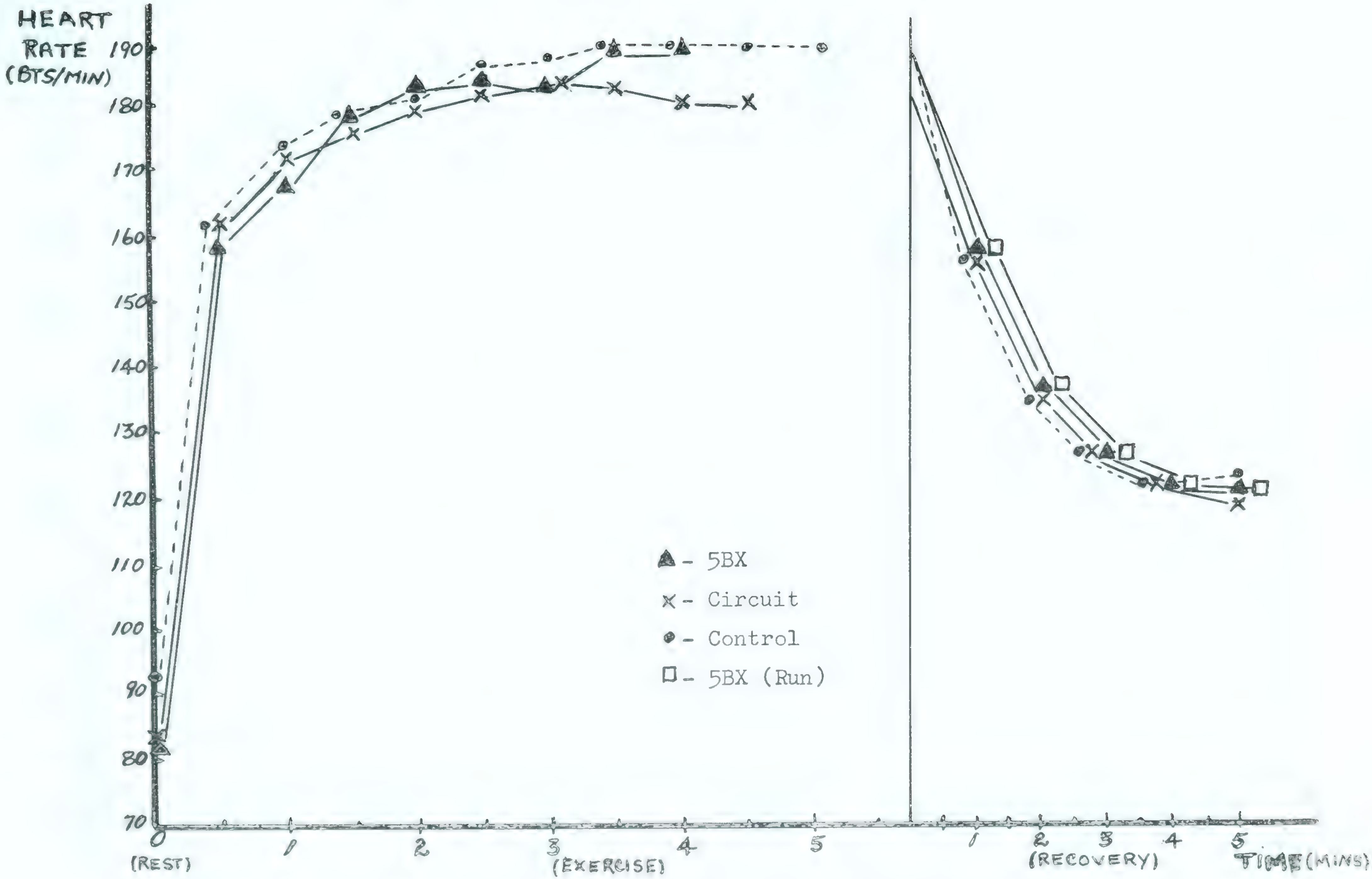


Figure 9. Mean Resting Exercise and Recovery Heart Rates For Initial Test Period Treadmill Run to Exhaustion.

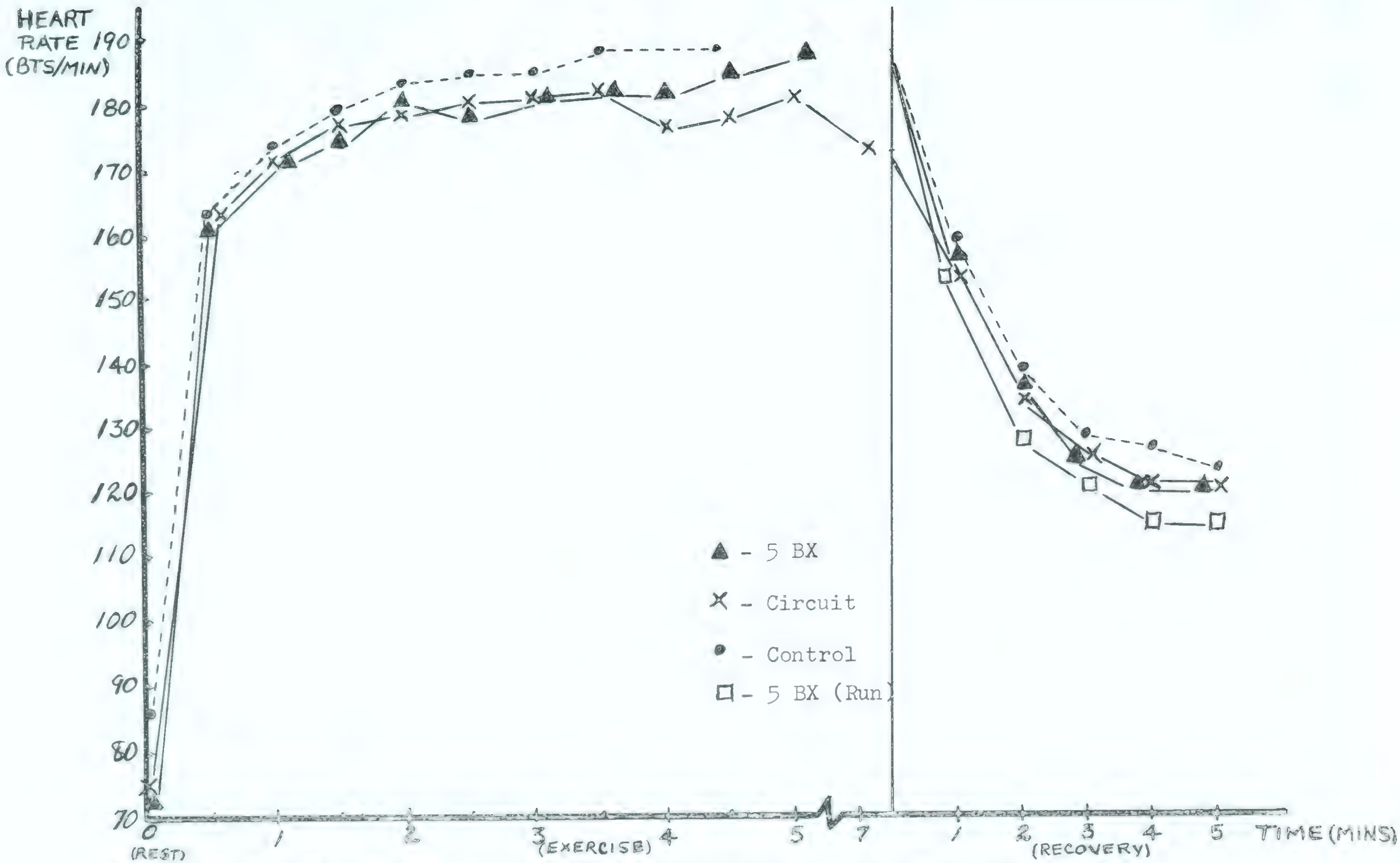


Figure 10. Mean Resting Exercise and Recovery Heart Rates For Final Test Period Treadmill Run To Exhaustion.

above the mean resting values. Recovery was therefore not complete after 5 minutes. All groups tended to follow this similar pattern, no distinction discernible between the groups. After 5 weeks of training little difference between the groups was observed in any of the recovery rates during the first 2 minutes (Fig. 8; Table XXIV App.C). However, the mean heart rates for the exercise groups over the final 3 minutes of recovery were approximately 3 beats/min. lower than control which remained unchanged (Fig. 17, 19, 21, 23, App.C). Of particular interest is the recovery heart rate of subgroup $A_2$ whose mean values were some 10 beats/min. lower than control during the second and third minutes. In this regard, Cureton (36:167) contends that a rapid recovery of the pulse rate to the resting level is one characteristic of fitness and is one of the most valid tests if the exercise is sufficiently intense.

The recovery heart rate pattern for the initial exhaustion run was almost identical for groups A, B and C (Fig. 9; Table XXV App.C). Heart rate decelerated much more slowly following the all-out effort than for the Balke-Ware test. This is in agreement with Morehouse (37:11). Mean heart rate values fell to 156 beats/min. during the first minute of recovery, then gradually dropped to 122 beats/min. after 5 minutes. Recovery heart rates for the exercise groups tended to remain unchanged following 5 weeks of training

while those for group C rose 3 - 5 beats/min. during each of the 5 recovery measurement intervals (Fig. 10; Table XXVII, Figs. 18, 20, 22, 24, App.C). This would tend to support the findings of Knehr and associates who observed: "We find that a regime of training which certainly increases physical fitness does not alter the decline of heart rate following exercise to complete exhaustion within an approximately constant time limit of 3 - 4 minutes" (8:155). Astrand also concurs (9:323). After the first minute of recovery, subgroup $A_2$ again tended to show recovery heart rates some 10 beats/min. lower than control. Contrary to the findings of Brouha and Heath (38) and in agreement with Durnin (39:165), it would seem then, that for the present study at least, recovery heart rates following exhausting exercise were of limited value as a criteria to determine differences in cardiovascular fitness..

(b) Oxygen Consumption. The individual's capacity for work depends largely upon his ability to take up, carry and deliver $O_2$ to the working tissues. Increased performance time, then, must be accompanied by an increased capacity of the circulo-respiratory system to supply more $O_2$ to the muscles. A large individual will also require a greater $O_2$ intake than will a smaller individual, all things being equal (40:143), (5:329). In order to compare the two individuals, some adjustment must be made which will account for this

difference in size. When body weight is divided out the relative efficiency or rate at which $O_2$ can be supplied for each kilogram of body weight is more clearly reflected (5:329), and according to Cureton is an excellent measure to use to rate the circulatory capacity of an individual (5:336).

After 5 weeks of training there was no change in the resting $O_2$ requirement for any of the groups. $O_2$ intake increased steadily with increased work load during exercise. After an initial rapid 3-fold rise from the resting level in the first minute of exercise, the $O_2$ intake assumed a level corresponding to the $O_2$ requirement of the work being performed. Supported by Erickson et al (41:393), Balke states (3:9) that $O_2$ consumption determined during walking on a motor driven treadmill, ". . . is influenced only by the amount of the work load and not by subjective factors." The Balke-Ware treadmill test, then, would tend to reflect any economizing effects of the training programs through a lessening of the $O_2$ requirement while performing the same amount of standardized work on the different tests. During the initial and final test periods, all subjects performed identical levels of work for the first 10 minutes of the Balke-Ware test. It was subsequently noted that during this 10 minute interval, no appreciable change occurred in the $O_2$ consumption for any of the groups between the initial and final testing periods (Fig. 11; Table XXVII, App.C). In most cases

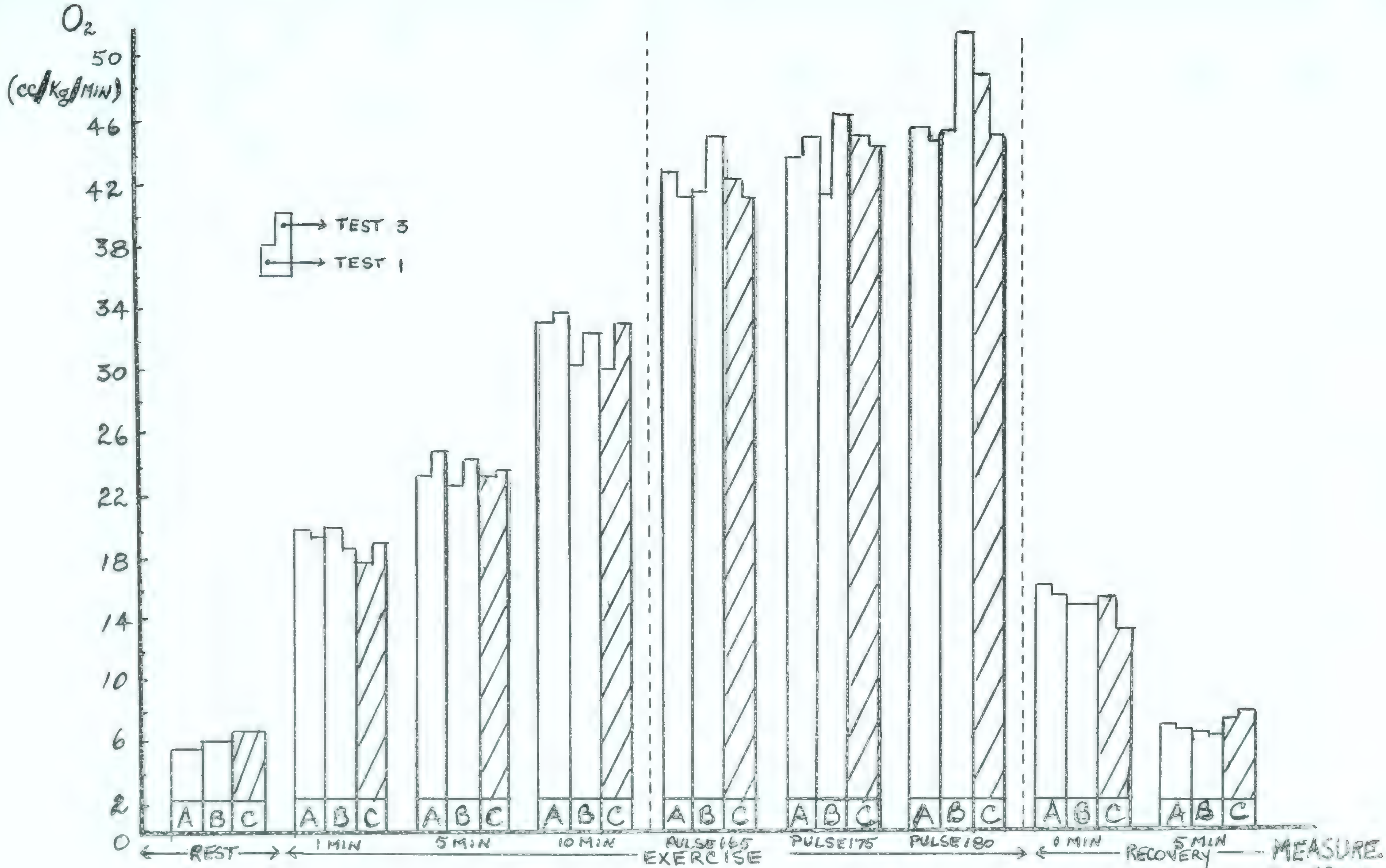


Figure 11. Oxygen Consumption Prior To And Immediately Following 5 Weeks Of Training Balke-Ware Treadmill Test.

the $O_2$ consumption for the final test was slightly higher (1.6cc/kg/min) than the initial values. This would seem to indicate that the exercise programs contributed little toward more efficient performance at the lower work intensities for this test. Beyond 10 minutes, considerable individual variation occurs in the time required by the subjects performing the Balke-Ware test to reach the terminal heart rate of 180 beats/min. For this reason, the intervals selected for obtaining the various physiologic measurements were based on pulse rates since all individuals were likely to reach the heart rates specified regardless of the variation in their performance times. It must be noted, however, that while all individuals attained the standardized pulse rate levels, the amount of work done by each subject prior to attaining these levels varied considerably. The $O_2$ consumed for the work done, therefore, would also exhibit inter and intra-group variations. Specific comparisons then would tend to be meaningless. This factor must also be considered where recovery data is concerned.

After 5 weeks of training the following general observations for standardized measurement intervals may be noted.

(1) Group A tended to use slightly less $O_2$ (1.6 cc/kg/min) while increasing their mean performance time by 54 seconds.

(2) Group B tended to require more $O_2$ (4.8 cc/kg/min)

to increase their mean performance time by 1.6 minutes.

(3) Group C tended to use slightly less $O_2$ (1.2 cc/kg/min) to accomplish a mean 42 seconds less work.

(4) During peak exercise, $O_2$ consumption increased approximately 8 times the resting level for all groups.

During the recovery period $O_2$ intake dropped very rapidly reaching a level approximately 30 cc/kg/min below terminal values by the end of the first minute. It was generally observed that little or no change occurred in the recovery $O_2$ consumption for groups A, B and C after 1 minute of exercise following the 5 week experimental period ($\pm$1.7 cc/kg/min). Five minutes after completion of exercise, recovery was almost complete for groups A and B on test 3, no change in the $O_2$ consumption noted over initial values. Recovery values for group C tended to be slightly higher (0.5 cc/kg/min) on test 3 than initially.

For the Balke-Ware treadmill test, then $O_2$ consumption remained fairly constant during the resting, exercise and recovery intervals concerned with the initial and final testing periods.

When interpretation of the data concerned with the $O_2$ consumption for the exhaustion run is undertaken, attention must be accorded several additional factors. In agreement with Balke (3:9) and Erickson <u>et al</u> (41), Taylor (40:123) confirms that training has little effect on the $O_2$ consump-

tion of walking. Walking is a familiar exercise for all individuals, consequently the degree of skill is high and the economizing effect of an improvement in skill does not occur. "On the other hand, in running it is easy to show that repetition by people who have done little or no running in the past reduces the $O_2$ requirement" (40:124). Also, the observation that at high rates of ventilation measurable amounts of $O_2$ varying from 400 - 1100 cc are required by the respiratory muscles (40:144) seems pertinent. Other factors like will power, neuromuscular conditions and relaxation may also be important elements affecting the running time and consequently the $O_2$ requirements of the individual as well (5:329).

In agreement with Hill (42:409), the rise in $O_2$ intake for the exhaustion run, from the low values characteristic of rest to the high values in excess of 50 cc/kg/min characteristic of the effort undertaken was realized within 2 minutes after exercise began for all tests (Fig. 12; Table XXVIII App.C). All subjects were able to run for 2 minutes at the speed of 7 mph and 8.6% grade, whereas only 4 subjects in each of the groups completed 3 minutes, or better, before the necessity arose to signal distress indicating that termination of the run was imminent. After 2 minutes of exercise then, the amount of work done by each subject prior to his terminal air sample varied greatly. This factor must also be

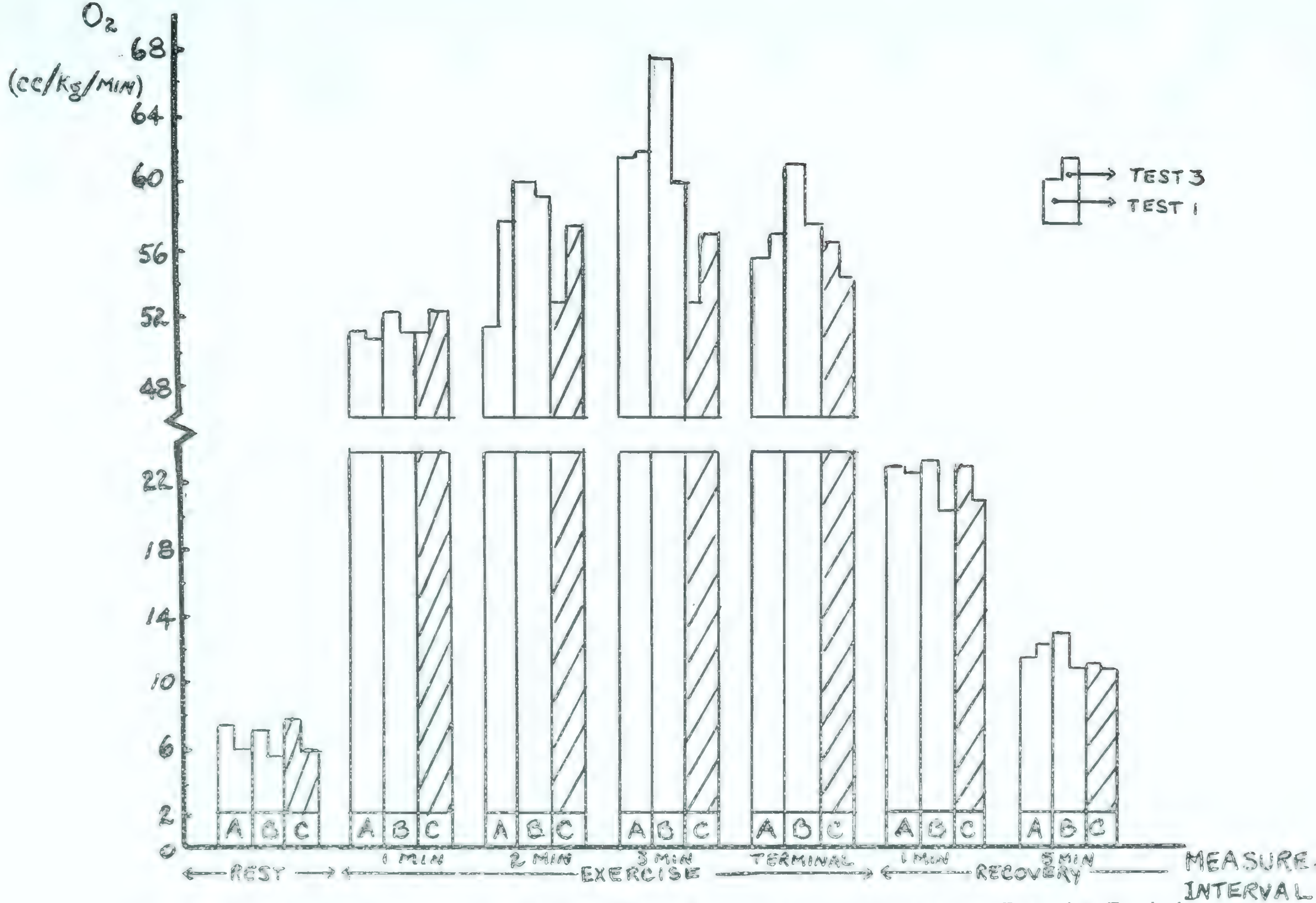


Figure 12. Oxygen Consumption Prior To And Immediately Following 5 Weeks Training Treadmill Run To Exhaustion.

considered when interpreting the data related to $O_2$ consumption of the exhaustion runs and to the subsequent recovery intake.

Group A's $O_2$ consumption remained relatively unchanged following 5 weeks of exercise. After 2 minutes of running on the final test, however, a mean rise in the $O_2$ intake of 6.4 cc/kg/min was observed. Some of this difference may be due to inefficient running where the subjects were still experimenting with their stride in order to determine the one best suited to the speed. This observation may be borne out in part by the higher $O_2$ consumption of group C during the same periods of the final run. Group B consistently tended to use less oxygen during all phases of the final run while increasing their mean performance time by 1.02 minutes. Considering the performance of groups A and C during this same testing period, it is unlikely that the acquisition of skill accounts entirely for the lower $O_2$ requirement for the circuit training group. Some effects of the training program are undoubtedly revealed here. The large reduction of 7.2 cc/kg/min in the $O_2$ intake observed during the 3 minute measurement interval is quite meaningful. While only 4 subjects in group B were able to complete 3 or more minutes without distress on the first running test, they were also the only 4 to similarly complete this time requirement on the final test. The fact that the decrease in $O_2$ consumption

was accompanied by an increase in mean performance time of 1 - 3 minutes for the 4 individuals would tend to reflect an increase in efficiency too large to be entirely attributed to learning during this measurement interval.

Peak $O_2$ values for the 3 groups tended to be some 10 times greater than the resting intakes during the running tests.

During the first minute of recovery from the exhaustion run mean $O_2$ intake values dropped sharply for all groups reaching a level 36 cc/kg/min lower than terminal values. After 5 minutes of recovery the $O_2$ consumption was still double the resting requirements. This would tend to agree with Krogh and Lindhard (43) who observed that the drop in $O_2$ consumption reached a fairly constant level after 3 minutes of recovery, ". . . the height of which depends on the intensity of the preceding work" (43:432).

With the possible exception of the circuit training group, then, 5 weeks of training did little to affect the exercise $O_2$ consumption during the treadmill run to exhaustion.

Subgroups $A_1$ and $A_2$ followed the trend established by groups A and B on both treadmill tests exhibiting little or no change in their initial $O_2$ intakes. The fact remains, however, that while no appreciable changes occurred in $O_2$ consumption after 5 weeks of training for groups A and B,

both groups were able to significantly increase their treadmill performance times on both tests. Relatively the same amount of $O_2$ then, was consumed by these groups to do more work. Consequently, the exercise programs would seem to have contributed in some degree at least to increased work efficiency.

(c) <u>The Respiratory Quotient</u>. Only when the body is in the basal state or the steady state of exercise does the R.Q. indicate the nature of the contemporary oxidation of food materials inside the body (33:38), (28:113), (44:74). At any other time it is simply the ratio of $CO_2$ being expired to the $O_2$ being absorbed by the respiratory organs at the moment in question. The term "respiratory quotient" has consequently been frequently misused especially in cases where it exceeds unity, since it does not reflect the true metabolic quotient at that time but rather obscures it. The writer wishes to establish that where the term R.Q. is used in this discussion the ventilatory R.Q. is implied unless otherwise indicated. The ventilatory R.Q., or respiratory exchange ratio, then, gives some information concerning the adaptability of the respiratory system to the work being done (3:1).

Resting R.Q.'s were computed from expired air samples taken immediately prior to each treadmill test. Initial and final mean values are reported in Table XVIII. Although the

subjects rested for 15 minutes prior to collection of expired air, the samples cannot be considered basal. Variations from the normally present basal R.Q. of .82 (28:113), can be explained by individual variations in diet (28:113), (45:270), (44:79), as well as by alterations in the rate and depth of respiration probably produced by the use of a mouthpiece, self-consciousness and/or apprehension (45:299), (46:463), (47:171), (44:74). Although minimized by the use of preliminary familiarization test runs, the influence of these contributing factors must still be considered.

TABLE XVIII

MEAN RESTING R. Q.'s

INITIAL AND FINAL TEST PERIODS

| GROUP | PRIOR TO BALKE-WARE TEST | | PRIOR TO EXHAUSTION RUN | |
|---|---|---|---|---|
| | 0 WEEKS | 5 WEEKS | 0 WEEKS | 5 WEEKS |
| A | .757 | .822 | .814 | .778 |
| B | .790 | .780 | .770 | .780 |
| C | .846 | .869 | .886 | .858 |
| $A_1$ | .726 | .770 | .806 | .800 |
| $A_2$ | .788 | .874 | .822 | .756 |

The mean exercise R.Q.'s for all groups performing the Balke-Ware Test fell below resting values during the first minute of exercise on both the initial and final test periods. R.Q.'s then slowly increased with increases in work load, attaining a level just below unity as the terminal pulse rate of 180 beats/min. was reached (Fig. 13; Table XXIX, App.C).

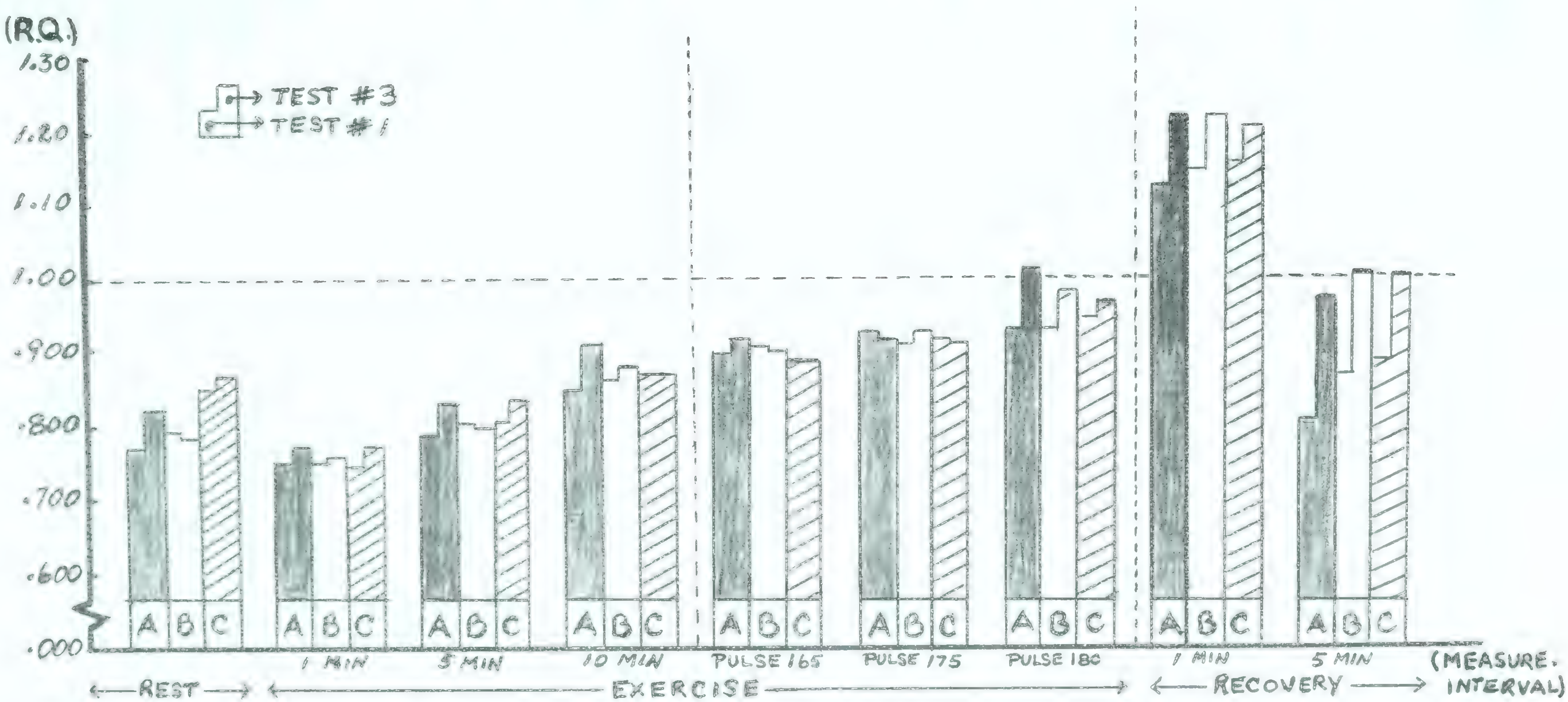


Figure 13. The Effect Of The Exercise Programs On The Respiratory Quotient As Determined By The Balke-Ware Treadmill Test.

Immediately following exercise, the R.Q's rapidly rose above unity during the first minute of recovery to values of 1.15 - 1.25. After 5 minutes of recovery, the R.Q.'s dropped to a level equal to or below 1.00. Following 5 weeks of training group A exhibited higher resting, exercise and recovery R.Q. values as did subgroups $A_1$ and $A_2$. Group B showed slightly lower resting R.Q.'s after the experimental period with relatively unchanged or slightly higher exercise values and much higher recovery values as compared to their initial performance. Group C showed little changed or slightly higher exercise R.Q.'s with increased values noted during rest and recovery intervals.

The steady rise in R.Q. during exercise exhibited by all groups performing the Balke-Ware test would suggest that although the work done was submaximal some lactic acid was accumulating resulting in the release, from the blood alkaline reserve, of $CO_2$ in excess of that derived from the oxidation processes going on in the body (46:466). With the onset of fatigue as work continued, a more rapid accumulation of lactic acid occurred resulting in an increased production and blowing off of $CO_2$ and higher R.Q. values. Luchsinger and Moser (28:114) report that during the first 1 or 2 minutes of exercise the R.Q. rises above unity then stabilizes between .9 and 1.0. They explain this rise in terms of an increased ventilatory volume accompanied by a

marked rise in $CO_2$ excretion, any increase in $O_2$ uptake being limited by the amount of blood perfusing the lungs. The fall in the mean R.Q. values observed during the first minute of exercise in this study is not in agreement with these previous findings. It is likely the difference lies with the intensity of the exercise being performed which the investigators did not stipulate. In the present study, the nature of the work during the first minute was very mild and the degree of individual skill very high (walking). Circulo-respiratory adjustments were consequently quickly and easily made with the onset of exercise. The increased pulmonary ventilation was not severe enough to deplete the alveolar stores of $CO_2$ to the extent that a compensating rapid excretion of $CO_2$ from the blood would need to occur. Figures 11 and 15 indicate that the rate of increase in $O_2$ consumption and $CO_2$ elimination during the first minute of exercise was approximately in the ratio of 3/2. This would account for the drop in R.Q. values during this measurement interval.

During the first minute of recovery, the mean R.Q.'s exceeded unity as $CO_2$ continued to be excreted in excess of the rate of $O_2$ consumption which rapidly fell as the result of diminished tissue requirements (Figs. 11, 15; Tables XXVII, XXXI, App.C). The level of ventilation remained above the tissue demands as a result of the stimulation of the respiratory center by the rise in hydrogen ion concentra-

tion of the blood induced by the high lactate level (47:464). Turrell and Robinson (48:742) observe: "An increase in blood lactate in human beings during exercise is accompanied by a decrease in base bound as bicarbonate consequently a decrease in the $CO_2$ combining capacity. This results in the associated extra output of $CO_2$ through the lungs." Later during recovery, lactic acid is chiefly removed by resynthesis to form glycogen (44:75). Free base is consequently left behind which immediately combines with $CO_2$ producing a retention of the latter, thereby exerting a depressing effect on the R.Q.

Cureton (5:341) states that the lower the exercise R.Q. the better the economy. Highly trained individuals tend to consume relatively large amounts of $O_2$. The very low R.Q. values reported for well conditioned athletes may be explained in part by this high $O_2$ intake during exercise. This is accompanied by an increased retention of $CO_2$ resulting from the previously mentioned buffering and resynthesis process producing a decreased $CO_2$ elimination (5:362). This effect of training was not revealed in the R.Q. values determined during the Balke-Ware test following 5 weeks of exercise for the experimental groups. The increased R.Q. values during the initial 10 minutes of work, especially those of group A, are difficult to understand since the work load was identical for all individuals during this interval. These higher values

for the trained groups would tend to support the findings of Crakes (49) who observed higher R.Q. values for the better runners in his study, an observation which, he states, is not reported in other studies. The slightly higher values exhibited by the trained groups over the other measurement intervals during exercise are not unlikely since these individuals worked longer during the final treadmill tests to reach these pulse levels. Group C showed relatively unchanged final R.Q. values while performing less work than initially. This may indicate a general lessening in the performance efficiency of their circulo-respiratory systems induced by their relative inactivity. The much elevated R.Q. recovery values for the exercise groups on the final test would tend to reflect the increased cost of performing more work on the final test. This was manifested by a greater accumulation of lactic acid and subsequent excess expulsion of $CO_2$ above initial values, and a greater $O_2$ debt. Since less work was performed by group C on the final test, the higher recovery R.Q. values may be attributed to mechanical and physiological inefficiency.

Mean R. Q. values determined during the exhaustion run tended to rise rapidly to a level near unity in the first minute of exercise (Fig. 14; Table XXX, App.C). An apparent plateauing of the R.Q.'s between 1.1 and 1.2 occurred for the remainder of the exercise period. During the first

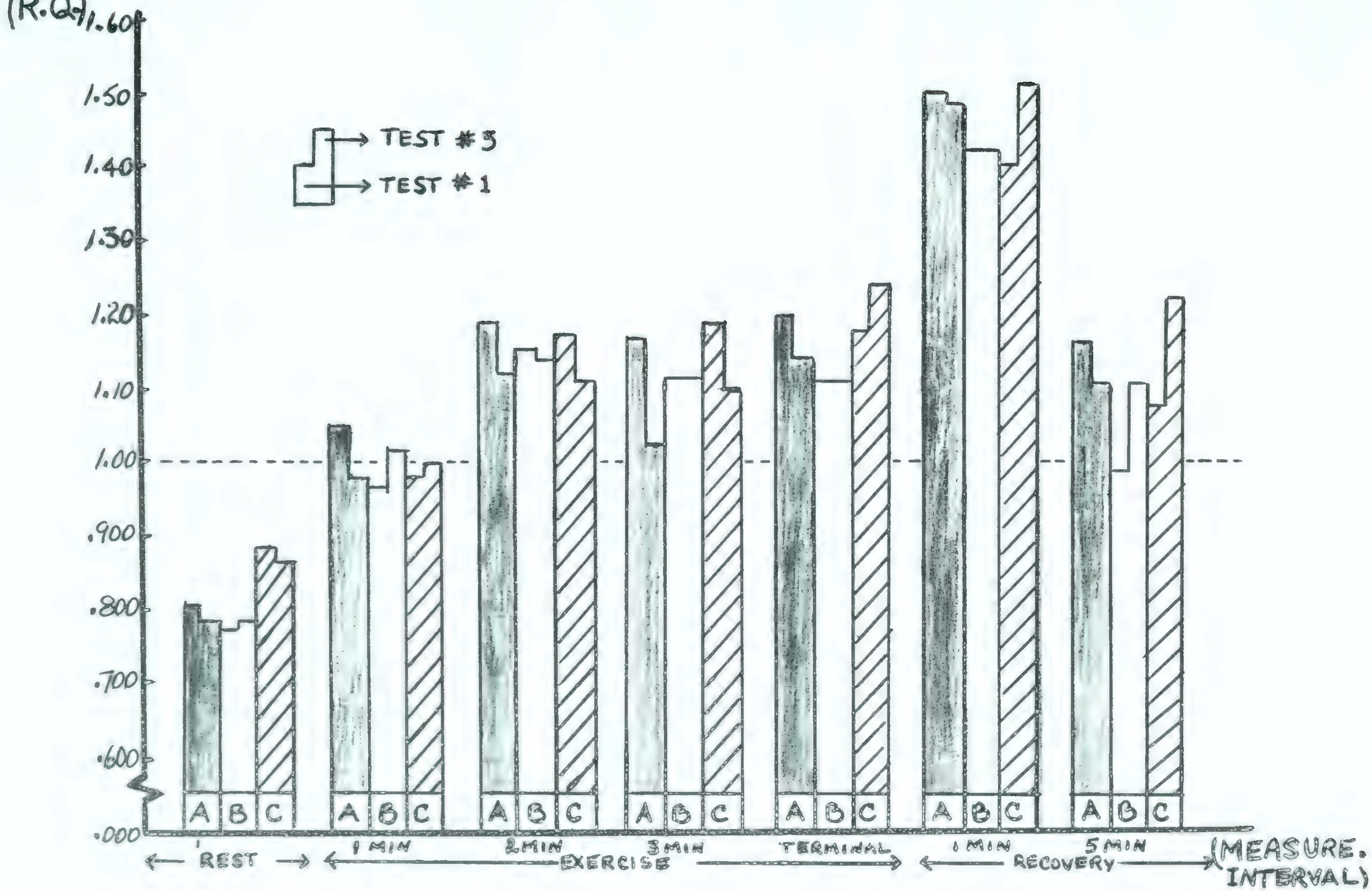


Figure 14. The Effect Of The Exercise Programs On The Respiratory Quotient As Determined By The Treadmill Run To Exhaustion.

minute of recovery following the exhaustion runs, R.Q.'s rose beyond the exercise values to 1.4 - 1.5. Recovery values determined during the fifth minute remained above unity near 1.15 - 1.20.

Group A exhibited lower resting, exercise and recovery R.Q.'s during the final exhaustion run. This was also true for subgroups $A_1$ and $A_2$. Group B tended to show relatively unchanged R.Q.'s following the 5 weeks of training with slightly higher values observed during the first minute of exercise and fifth minute of recovery. Group C showed a slightly lowered resting R.Q. during the final run, a marked inconsistency in the exercise R.Q. and much higher recovery values.

Reduction in mean resting R.Q.'s were moderate and can probably be attributed to a lessening of psychological factors. R.Q. values in excess of unity for severe exercise of short duration are widely reported (45), (46), (50). Hill, Long and Lupton advise:

> When we realize that in very severe exercise a vigorous man may produce 2 - 3 gms of lactic acid/sec., it will be obvious that there is no difficulty explaining even the most violent alterations of the R.Q. on the basis of lactic acid changes (46:464).

It has been observed that R.Q.'s exceeding unity appear only in cases where the circulo-respiratory system is overtaxed (51:131), (3:9). It is likely then that the ventilatory

R.Q. can become an indication of the optimal capacity of cardio-respiratory efficiency during maximum work. It is interesting to note that group A exhibited a marked improvement in this optimal capacity during the final exhaustion run which is precisely contrary to indications exhibited by the data for this group during the Balke-Ware test. Apparently the more severe test was necessary to bring out this improvement, which in part must be attributed to the training program. Group B tended to show relatively unchanged R.Q. values during exercise which theoretically may also represent a gain in physiological efficiency since more work was performed. The data for group C would tend to indicate more stress to do the same amount of work.

The respiratory quotient, then, as determined during the Balke-Ware treadmill test revealed no tendency to attain the lower exercise values reported as being indicative of the effects of training, for either of the exercise groups following 5 weeks of training. Concomitant with the increase in performance time was the trend to higher R.Q. values. With the exception of group A the same observations were true during the exhaustion runs. Group A exhibited a consistent trend toward lower R.Q. values during rest, exercise and recovery during the final exhaustion run test period.

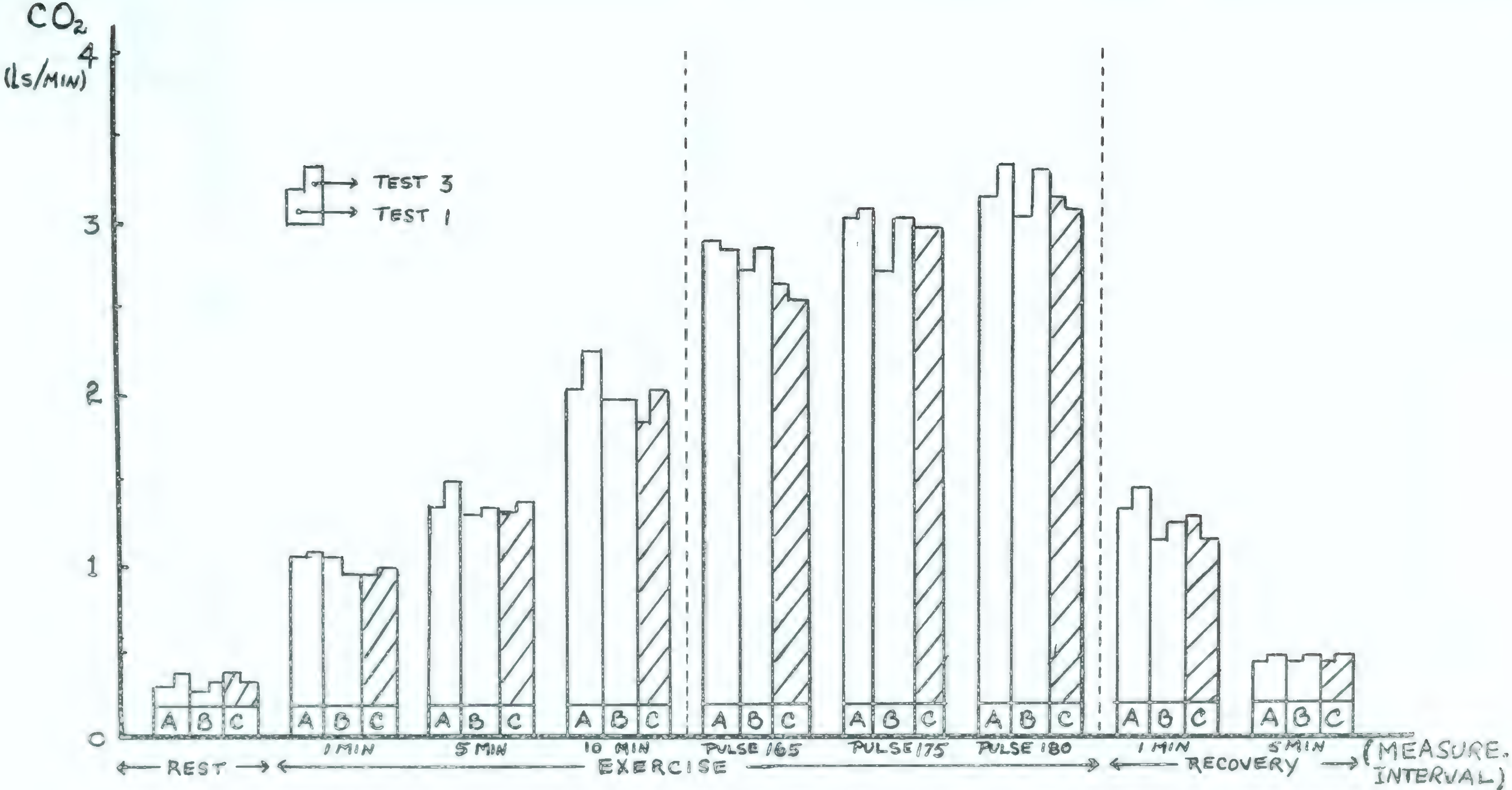


Figure 15. Carbon Dioxide Elimination Prior To And Immediately Following 5 Weeks of Training Balke-Ware Treadmill Test.

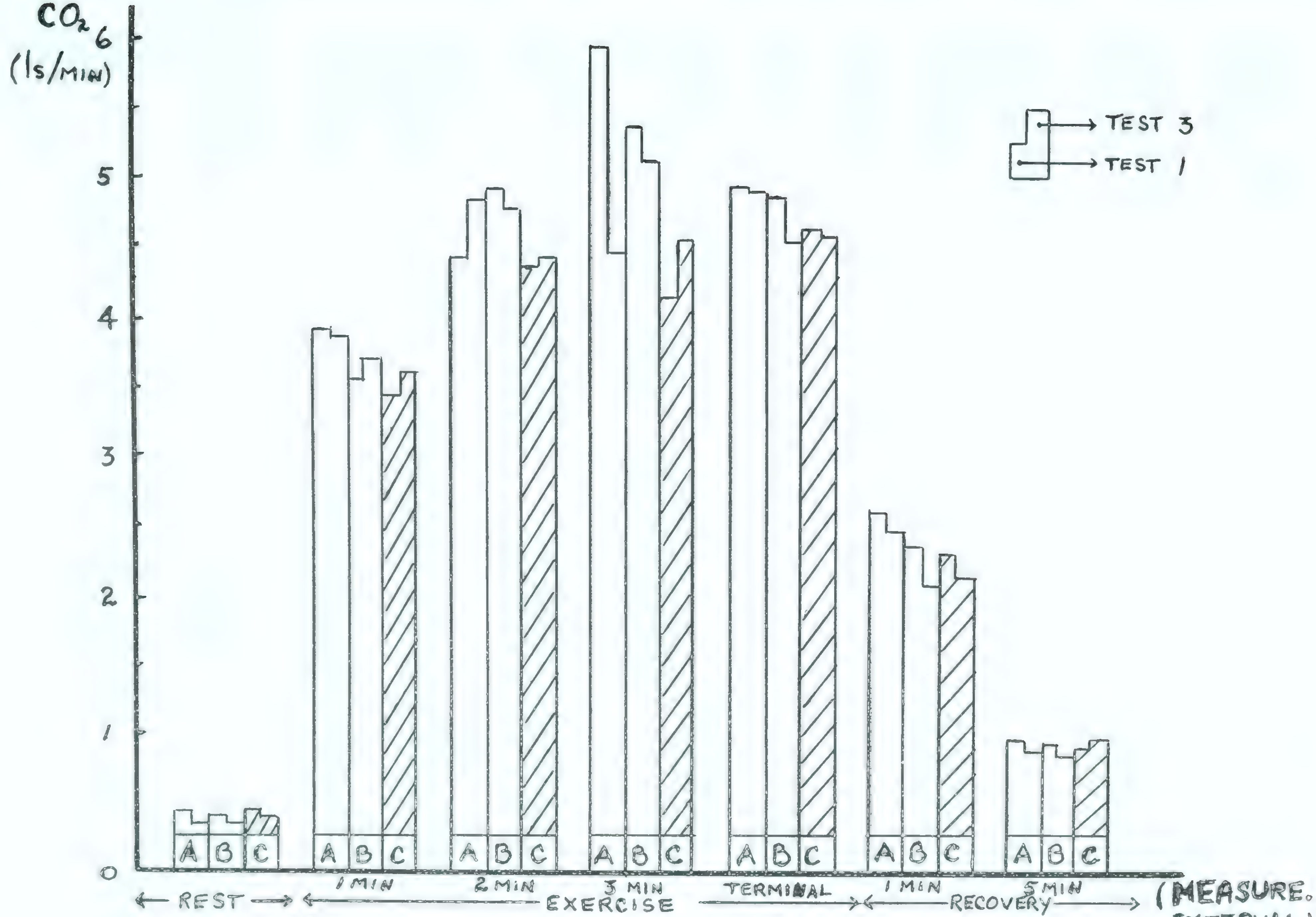


Figure 16. Carbon Dioxide Elimination Prior To And Immediately Following 5 Weeks of Training. Treadmill Run To Exhaustion.

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CHAPTER V

SUMMARY AND CONCLUSIONS

Summary. The purpose of this study was to compare the effects of two types of exercise programs, one a short intensive program (5BX), the other a more prolonged intensive program (circuit training), on the basis of their contribution to cardio-respiratory fitness. Thirty healthy male subjects, mean age 19.65 years, were selected at random from the general student body attending the University of Alberta. All subjects were equated on the basis of their performance times on a preliminary Balke-Ware treadmill test then divided into 3 matched groups of 10 members each. Group A participated in the 5BX program, group B in a 13 station circuit training program, group C acted as control. Group A was divided into subgroups $A_1$ and $A_2$. Both subgroups performed the first four 5BX exercises as prescribed by the 5BX manual. As their 5th activity $A_1$ was required to run on the spot as specified, and $A_2$ the designated distance in order to determine whether the 2 programs were equivalent in their contribution to cardio-respiratory fitness. The exercise programs were continued 5 days a week for 5 weeks. The Balke-Ware treadmill test (3.4 mph, grade increased 1%/min. terminating at a heart rate of 180 beats/min.), an all-out treadmill run to exhaustion (7mph, 8.6% grade), and a maximum breathing capacity

test were administered to each subject immediately before, after 2.5 weeks and upon completion of the exercise programs. Cardio-respiratory parameters investigated included heart rate, $O_2$ consumption and $CO_2$ elimination, and the ventilatory R.Q. at rest, during exercise and during 5 minutes of recovery. During the Balke-Ware test heart rates were recorded at rest, every minute during exercise until a pulse rate of 165 beats/min. was reached where it was recorded every 30 seconds until 180 beats/min. was attained, and every minute for 5 minutes during recovery. Heart rates were similarly recorded for the exhaustion run with the exception that exercise values were obtained every 30 seconds. Using Douglas Bags, expired air was collected (a) for 30 seconds at rest prior to both treadmill tests, (b) for 15 seconds after 1, 5, and 10 minutes of work and when the pulse reached 165, 175 and 180 beats/min. during the Balke-Ware test, (c) for 15 seconds after 1, 2, and 3 minutes of exercise during the exhaustion run plus a 15 second terminal sample, and (d) for 15 seconds for each minute of the 5 minute recovery period for both tests. The expired air volumes were corrected to STPD and analysed for $O_2$ and $CO_2$ content for each subject during each of these measurement intervals.

The following observations were made after completion of the 5 week experimental period.

(1) The mean gains of 1.6 minutes for group B (circuit)

and 1.7 minutes for subgroup $A_2$ (5BX plus running distance) between initial and final Balke-Ware tests were statistically significant ($p < .05$). Group B ($p < .05$) and subgroup $A_2$ ($p < .01$) were also statistically superior to control on final test performance. Although a considerable distinction (1.6 mins.) existed between $A_2$ and $A_1$ (5BX plus spot running) on the final test, the difference was not statistically significant ($p > .05$, $n = 5$).

(2) The mean gains of 54 seconds by group A and 1.02 minutes by group B between the initial and final treadmill runs to exhaustion were statistically significant ($p < .02$). Subgroups $A_1$ and $A_2$ with mean gains of 43 and 52 seconds respectively also increased significantly ($p < .05$) between initial and final performances. No statistically significant difference between any of the groups was evident during the final exhaustion runs.

(3) Only group B, with a mean gain of 20.8 l/min. improved significantly in MBC after 5 weeks of training ($p < .02$). While subgroup $A_1$ was distinctly superior to $A_2$ (28.9 l/min.), this difference between the groups on the final test was not significant ($p > .05$, $n = 5$). No statistical difference existed between any of the groups during the final test period.

(4) While resting heart rates recorded prior to each treadmill test were lower for all groups, they were significantly lower only for group A and only prior to the exhaustion

run. Inspite of the reduced final resting values for control, mean heart rates for this group remained some 10 beats/min. higher than those for the experimental groups. Groups A and B showed reduced resting values of 2 - 9 beats/min. The trend for the heart rates recorded during exercise for the Balke-Ware and exhaustion tests was virtually the same with exercise heart rate values 2 - 5 beats/min. higher than initially for control and 2 - 5 beats/min. lower than initially for the experimental groups. Group A showed a greater reduction in exercise heart rate than group B. Recovery heart rate values remained unchanged for the control group following the final Balke-Ware test, the exercise groups exhibiting a reduction of from 1 - 4 beats/min. from initial test values. No change was observed in the recovery heart rates for groups A and B following the final exhaustion runs while recovery values for group C rose 2 - 6 beats/min. Groups A and B exhibited no difference between recovery heart rate values. Subgroup $A_2$ consistently showed lower resting (7 beats/min.), exercise (2 - 7 beats/min.) and recovery (2 - 12 beats/min.) values than $A_1$ during both final treadmill tests.

(5) No change in the resting $O_2$ consumption was observed for any of the groups prior to the final Balke-Ware test. All groups tended to consume less $O_2$ during the rest interval preceeding the final exhaustion run tests than they did initially.

With the exception of group B which consistently indicated reduced resting, exercise and recovery $O_2$ intake during the final exhaustion run, exercise $O_2$ consumption tended to be higher, and recovery intakes lower, for all groups during the final performance of both treadmill tests than initially. Subgroup $A_2$ tended to consume less $O_2$ than initially for final performances during rest, exercise and recovery intervals during both treadmill tests than did $A_1$.

(6) Values for the ventilatory R.Q. were greater than initially for all groups during rest, exercise and recovery intervals associated with the final Balke-Ware test. Group A exhibited distinctly lowered resting, exercise and recovery R.Q. values during the final exhaustion run than during the first test period, while R.Q. values determined during these intervals for group B remained relatively unchanged, those for group C, especially during exercise, tending to fluctuate greatly. Subgroup $A_2$ indicated slightly higher R.Q. values than $A_1$ for the resting, exercise and recovery intervals during the final Balke-Ware test but exhibited distinctly lower final R.Q. values than $A_1$ during the same intervals associated with the final exhaustion run.

## Conclusions.

(1) Gains in treadmill performance times by the 5BX and circuit training groups during the final Balke-Ware and exhaustion run tests would indicate that both exercise programs

contributed in some degree to significant increases in cardio-respiratory fitness.

(2) The circuit training group showed greater gains during the final MBC tests than did the 5BX group. Final test data, however, suggest that the learning factor may contribute significantly to these gains. As administered in this study then, the resting MBC test did not provide a satisfactory measure of respiratory function.

(3) Both experimental groups exhibited generally lower resting, exercise and recovery heart rates and $O_2$ intake after the experimental period than control. With the exception of group A during the exhaustion run, ventilatory R.Q. values remained unchanged or were higher than initially.

(4) The 5BX group running distance consistently exhibited superior gains in treadmill performance and in economy associated with the cardio-respiratory variables investigated. It is clearly indicated that if maximum benefit is to be derived from the 5BX program, running the distance specified must be included as the 5th basic exercise.

(5) Although not statistically supported in all cases, the data tends to indicate that the type of circuit training employed in this study may contribute more to gains in cardio-respiratory fitness than the composite 5BX program. When the data for the 5BX group running distance is compared with that for the circuit group, however, little difference exists be-

between final performance scores for these two groups. It becomes apparent then, that the quality and intensity of the exercise is more important than the quantity and duration.

Recommendations.

(1) In order that the degree to which running per se contributes to cardio-respiratory gains attributed to the 5 BX program a study similar to the present investigation should be conducted comparing performances of groups engaging in (a) 5BX plus spot running, (b) 5BX plus running distance, and (c) running the 1 mile distance only.

(2) In order to determine the trends beyond 5 weeks of training, a study paralleling the present investigation should be conducted over a training period of 10 - 15 weeks. Apparently the 5BX program contributes significantly to gains in cardio-respiratory fitness for low fitness groups. The present study raises some doubt as to the relative contribution of this program to the individuals who are more fit. Also, the same type of investigation involving another form of circuit training purported to contribute to gains in cardio-respiratory fitness would be informative.

(3) The use of the MBC test as a test of respiratory adaptation to exercise for the healthy active young male appears to be invalid. Also, testing methods and procedures must be standardized and norms established so that valid comparisons can be made and meaningful conclusions drawn.

Where future studies are conducted implementing the resting MBC test, it is highly recommended, in order to minimize the influence of the learning factor and to establish a more reliable base line value from which to proceed, that each subject be required to undertake several preliminary trials on the testing apparatus over a period of several days.

Appendum.

It is apparent that the greatest single limitation to progression to the higher levels of the 5BX program is the push-up exercise, the intensity of which seems to be out of proportion to that of the other exercises. Most subjects in group A were unable to complete the number of repetitions prescribed when they reached chart 3, particularly after the B- level. It is recommended that this aspect of the program be investigated and revised as necessary.

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# A P P E N D I X   A

TABLE XIX

TESTS OF HOMOGENEITY OF VARIANCE INITIAL TEST SCORES

| GROUP VAR. | EXHAUSTION RUN | | GROUP VAR. | RESTING MBC | |
|---|---|---|---|---|---|
| | F | P | | F | P |
| $s_A^2 = 132.03$ | $\frac{B}{A} = 1.72$ | $p > .10$ | $s_A^2 = 791.63$ | $\frac{B}{A} = 1.03$ | $p > .10$ |
| $s_B^2 = 226.49$ | $\frac{C}{A} = 2.27$ | $p > .10$ | $s_B^2 = 816.89$ | $\frac{A}{C} = 1.01$ | $p > .10$ |
| $s_C^2 = 299.49$ | $\frac{C}{B} = 1.32$ | $p > .10$ | $s_C^2 = 783.34$ | $\frac{B}{C} = 1.04$ | $p > .10$ |

TABLE XX

TESTS OF SIGNIFICANCE VS. MEANS INITIAL TEST SCORES

| GROUPS COMPARED | | DIFFERENCES VS. MEANS | ST. ERROR OF DIFFS. | t | p |
|---|---|---|---|---|---|
| A - B | MBC | 3.0 | 40.11 | 0.075 | $> .50$ |
| | TER | 27.9 | 18.94 | 1.473 | $< .20$ |
| A - C | MBC | 0.9 | 39.69 | 0.023 | $> .50$ |
| | TER | 25.9 | 20.77 | 1.247 | $> .20$ |
| B - C | MBC | 3.9 | 40.00 | 0.098 | $> .50$ |
| | TER | 2.0 | 22.93 | 0.087 | $> .50$ |

TER - Treadmill Exhaustion Run

# STATISTICAL FORMULAE

The following computatimal formulae were employed where required:

(a) Standard Deviation (Unbiased).

$$s = \sqrt{\frac{\Sigma X^2 - \frac{(\Sigma X)^2}{N}}{N - 1}}$$

(b) F Ratio Test for Homogeneity of Variance (Independent Samples.

$$F = \frac{s_1^2}{s_2^2} \quad \text{where} \quad s_1^2 = \frac{\Sigma X_1^2 - \frac{(\Sigma X_1)^2}{n_1}}{n_1 - 1}$$

$$s_2^2 = \frac{\Sigma X_2^2 - \frac{(\Sigma X_2)^2}{n_2}}{n_2 - 1}$$

$df = n_1 - 1,\ n_2 - 1$ for numerator and denominator respectively.

(c) Homogeneity of Variance (Correlated Samples).

$$t = \frac{(s_1^2 - s_2^2)\sqrt{N - 2}}{\sqrt{4s_1^2 s_2^2\ (1 - r_{xy}^2)}} \quad \text{where} \quad r_{xy} = \frac{\Sigma xy}{Ns_x s_y}$$

$$x = (X - \bar{X})$$

$$y = (Y - \bar{Y})$$

$$s_x = \sqrt{\frac{\Sigma x^2}{N}}$$

$$s_y = \sqrt{\frac{\Sigma y^2}{N}}$$

$df = N - 2$

(d) <u>Significance of the Difference Between Two Means (Independent Samples)</u>.

$$t = \frac{\bar{X}_1 - \bar{X}_2}{s_{\bar{x}_1 - \bar{x}_2}} \quad \text{where} \quad s_{\bar{x}_1} - s_{\bar{x}_2} = \sqrt{(s^2/N_1) + (s^2/N_2)}$$

$$s^2 = \frac{\left[\Sigma X_1^2 - \dfrac{(\Sigma X_1)^2}{N_1}\right] \left[\Sigma X_2^2 - \dfrac{(\Sigma X_2)^2}{N_2}\right]}{N_1 + N_2 - 2}$$

$$df = N_1 + N_2 - 2$$

(e) <u>Significance of the Difference Between Two Means (Correlated Samples)</u>.

$$t = \frac{\bar{D}}{s_{\bar{D}}} \quad \text{where} \quad s_D^2 = \frac{\Sigma D^2 - \dfrac{(\Sigma D)^2}{N}}{N - 1}$$

$$s_{\bar{D}} = \sqrt{s_D^2/N - 1}$$

$$df = N - 1$$

(f) <u>Correlation Coefficient for Ungrouped Data</u>.

$$r = \frac{\Sigma xy}{N s_x s_y}$$ see part (c) above

# A P P E N D I X B

TABLE XXI

CIRCUIT TRAINING ITEMS, WEIGHTS AND REPETITIONS (U. of Alta.) AS STATED BY HOWELL AND MORFORD

| No. | ITEM | RED CIRCUIT Wt. (lbs.) | RED 1 | RED 2 | RED 3 | BLUE CIRCUIT Wt. (lbs.) | BLUE 1 | BLUE 2 | BLUE 3 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Squat Thrust | -- | 10 | 12 | 15 | -- | 18 | 21 | 25 |
| 2 | Two Arm Curl | 40 | 8 | 10 | 12 | 50 | 8 | 10 | 12 |
| 3 | Two Arm Press | 50 | 8 | 10 | 12 | 60 | 8 | 10 | 12 |
| 4 | Straddle Bench Jumps | 15 | 15 | 17 | 19 | 25 | 17 | 18 | 19 |
| 5 | Lateral Raise | 7.5 | 8 | 10 | 12 | 10 | 8 | 10 | 12 |
| 6 | Lying Lateral Raise | 10 | 8 | 10 | 12 | 15 | 8 | 10 | 12 |
| 7 | Sit-Ups | -- | 10 | 14 | 18 | -- | 21 | 25 | 30 |
| 8 | Bench Step Ups | -- | 15 | 17 | 20 | -- | 23 | 26 | 30 |
| 9 | Jump Chins | -- | 1 | 2 | 3 | -- | 4 | 6 | 8 |
| 10 | Bench Press | 60 | 6 | 8 | 10 | 80 | 6 | 8 | 10 |
| 11 | Trunk Extension | -- | 10 | 12 | 14 | -- | 16 | 18 | 20 |
| 12 | Bent Over Rowing | 65 | 6 | 8 | 10 | 85 | 6 | 8 | 10 |
| 13 | Stair Running | -- | 6 | 8 | 10 | 10 | 6 | 8 | 10 |

Target Time: 25 mins. for 3 laps of circuit.

Exercises Described:

1. Squat Thrust - From standing position drop to squat position, hands 8" - 12" in front of the feet. Look straight ahead. Extend the legs back keeping body straight. Return to squat position

feet 8" - 12" from the hands. Stand completely erect and repeat.

2. Two Arm Curl - Supinated grip, clear position. Raise the bar to shoulder level, lower and repeat.

3. Two Arm Military Press - Pronated grip, clear position. Push the bar close to the face until the arms are fully extended, lower and repeat.

4. Straddle Bench Jumps - Feet astride an 18" bench, dumbell in each hand. Look straight ahead. Jump to a position on the bench, jump back to the floor and repeat.

5. Lateral Raise - Face straight ahead, legs spread, dumbell in each hand close to sides of body. Raise arms to horizontal position, lower and repeat.

6. Lying Lateral Raise - Supine position on a bench, arms spread and straight, dumbell in each hand close to the floor. Bring hands together, lower and repeat.

7. Sit Ups - Legs either straight or bent, hands behind neck, feet secured preferably by a bar. Body is raised to the sitting position and lowered; repeat.

8. Bench Step Ups - From standing position, left foot is placed on bench, then the right. The individual now moves to upright position on top of bench. Left leg returns to floor, then the right. Repeat. The starting leg may be changed for convenience.

9. Jump Chins - Front standing position, legs slightly bent. Jump and grasp bar, pull until chin is level with the bar. Drop to floor and repeat.

10. Bench Press - Supine position on bench, feet flat on floor, head between barbell rest. Take the barbell off the rest, arms straight, lower the bar to the chest, raise and repeat.

11. Trunk Extension - Prone position, hands behind neck, feet secured by a padded bar, thighs resting on an inclined level. Raise body as high as possible by arching upward. Lower and repeat.

12. Bent Over Rowing - Pronated grip, legs straight bent over (body at right angles to legs), look straight ahead, back straight. Raise barbell to chest, lower until arms fully extended, repeat.

13. Stair Running - Using bleachers run to top, turn and run down. Repeat. For added difficulty carry dumbells.

TABLE XXI A

EXERCISE LEVELS ATTAINED BY EXPERIMENTAL GROUPS

| CIRCUIT | | | | 5 BX | | | |
|---|---|---|---|---|---|---|---|
| SUBJECT | START | 2.5 WKS. | 5 WKS. | SUBJECT | START | 2.5 WKS. | 5 WKS. |
| K.A. | $R_1$ | $B_1$ | $B_2$ | G.L.* | IB- | 3A+ | 4A+ |
| K.E. | $R_1$ | $R_3$ | $B_2$ | H.R. | IB- | 3C | 3B |
| M.W. | $R_1$ | $R_2$ | $R_2$ | B.M. | IB- | 4D- | 4C+ |
| D.K. | $R_1$ | $R_2$ | $R_3$ | R.Q.* | IB- | 4C+ | 5C+ |
| S.T. | $R_1$ | $R_3$ | $B_1$ | D.S. | IB- | 3D- | 4D |
| J.L. | $R_1$ | $B_1$ | $B_2$ | D.W.* | IB- | 3B+ | 4C+ |
| F.A. | $R_1$ | $R_3$ | $B_1$ | S.H.* | IB- | 3A | 4B+ |
| G.K. | $R_1$ | $B_2$ | $B_3$ | W.H. | IB- | 2A+ | 3C+ |
| S.M. | $R_1$ | $R_1$ | $R_1$ | B.H.* | IB- | 3A+ | 4D- |
| R.H. | $R_1$ | $R_3$ | $B_1$ | H.C. | IB- | 3B- | 4D- |

* Ran Distance

# A P P E N D I X C

TABLE XXII

MEAN HEART RATES BALKE-WARE TREADMILL TEST

FIRST TEST PERIOD

| GROUP | MINS. | A | $A_1$ | A2 | B | C |
|---|---|---|---|---|---|---|
| REST | | 78 | 79 | 76 | 81 | 95 |
| EXERCISE | 1 | 110 | 110 | 111 | 129 | 119 |
| | 2 | 105 | 102 | 107 | 115 | 114 |
| | 3 | 107 | 107 | 108 | 119 | 115 |
| | 4 | 112 | 113 | 110 | 119 | 119 |
| | 5 | 115 | 111 | 118 | 130 | 125 |
| | 6 | 120 | 120 | 120 | 127 | 125 |
| | 7 | 124 | 124 | 125 | 131 | 130 |
| | 8 | 128 | 127 | 129 | 137 | 137 |
| | 9 | 133 | 133 | 134 | 139 | 142 |
| | 10 | 141 | 139 | 142 | 149 | 144 |
| | 11 | 148 | 148 | 148 | 151 | 149 |
| | 12 | 154 | 153 | 155 | 153 | 156 |
| | 13 | 156 | 153 | 158 | 158 | 162 |
| | 14 | 160 | 158 | 162 | 163 | 165 |
| | 15 | 161 | 160 | 162 | 164 | 168 |
| | 16 | 169 | 166 | 172 | 168 | 172 |
| | 17 | 173 | 169 | 177 | 169 | 173 |
| | 18 | 173 | 170 | 177 | 174 | 175 |
| | 19 | 173 | 173 | 177 | 173 | 180. |
| | 20 | 180. | 180. | 180. | 173 | |
| | 21 | | | | 173 | |
| | 22 | | | | 180 | |
| | 23 | | | | | |
| | 24 | | | | | |
| RECOVERY | 1 | 141 | 145 | 137 | 138 | 141 |
| | 2 | 124 | 130 | 117 | 122 | 125 |
| | 3 | 116 | 118 | 113 | 115 | 118 |
| | 4 | 113 | 115 | 111 | 112 | 114 |
| | 5 | 113 | 115 | 110 | 111 | 110 |

(NOTE: 180. means add 1/2 min. to indicated time.)

TABLE XXIII

MEAN HEART RATES BALKE-WARE TREADMILL TEST

SECOND TEST PERIOD

| GROUP | | A | $A_1$ | $A_2$ | B | C |
|---|---|---|---|---|---|---|
| REST | | 77 | 77 | 78 | 78 | 90 |
| | MINS. | | | | | |
| EXERCISE | 1 | 113 | 115 | 112 | 121 | 120 |
| | 2 | 111 | 113 | 109 | 117 | 117 |
| | 3 | 112 | 113 | 112 | 122 | 119 |
| | 4 | 117 | 118 | 116 | 124 | 123 |
| | 5 | 121 | 121 | 122 | 129 | 128 |
| | 6 | 125 | 126 | 125 | 131 | 131 |
| | 7 | 130 | 131 | 130 | 136 | 136 |
| | 8 | 134 | 135 | 134 | 140 | 141 |
| | 9 | 141 | 142 | 140 | 146 | 142 |
| | 10 | 148 | 149 | 146 | 148 | 149 |
| | 11 | 150 | 151 | 150 | 152 | 154 |
| | 12 | 156 | 157 | 154 | 156 | 160 |
| | 13 | 162 | 164 | 160 | 162 | 162 |
| | 14 | 164 | 166 | 162 | 163 | 166 |
| | 15 | 165 | 166 | 165 | 165 | 172 |
| | 16 | 169 | 169 | 169 | 168 | 176 |
| | 17 | 171 | 171 | 172 | 170 | 173 |
| | 18 | 172 | 173 | 171 | 171 | 180. |
| | 19 | 175 | 178 | 175 | 168 | |
| | 20 | 175 | 178 | 178 | 173 | |
| | 21 | 178 | 180 | 178 | 173 | |
| | 22 | 180 | | 180 | 180. | |
| | 23 | | | | | |
| | 24 | | | | | |
| RECOVERY | 1 | 139 | 140 | 139 | 137 | 140 |
| | 2 | 122 | 124 | 119 | 122 | 125 |
| | 3 | 114 | 116 | 111 | 117 | 114 |
| | 4 | 109 | 109 | 110 | 113 | 113 |
| | 5 | 109 | 109 | 109 | 112 | 110 |

TABLE XXIV

MEAN HEART RATES BALKE-WARE TREADMILL TEST

THIRD TEST PERIOD

| GROUP | MINS. | A | $A_1$ | $A_2$ | B | C |
|---|---|---|---|---|---|---|
| REST | | 76 | 81 | 71 | 76 | 88 |
| EXERCISE | 1 | 113 | 111 | 115 | 116 | 113 |
| | 2 | 113 | 111 | 114 | 115 | 117 |
| | 3 | 113 | 112 | 114 | 120 | 117 |
| | 4 | 116 | 116 | 117 | 120 | 120 |
| | 5 | 121 | 120 | 123 | 124 | 124 |
| | 6 | 124 | 125 | 123 | 127 | 127 |
| | 7 | 129 | 130 | 129 | 133 | 132 |
| | 8 | 133 | 131 | 135 | 135 | 136 |
| | 9 | 138 | 138 | 138 | 140 | 142 |
| | 10 | 143 | 144 | 142 | 145 | 146 |
| | 11 | 149 | 152 | 146 | 150 | 153 |
| | 12 | 154 | 155 | 154 | 154 | 161 |
| | 13 | 159 | 161 | 157 | 159 | 165 |
| | 14 | 165 | 167 | 161 | 161 | 171 |
| | 15 | 168 | 170 | 166 | 165 | 172 |
| | 16 | 169 | 170 | 169 | 167 | 174 |
| | 17 | 172 | 170 | 174 | 170 | 177 |
| | 18 | 173 | 173 | 173 | 172 | 177 |
| | 19 | 178 | 173 | 178 | 173 | 180 |
| | 20 | 180. | 180. | 180. | 166 | |
| | 21 | | | | 173 | |
| | 22 | | | | 173 | |
| | 23 | | | | 173 | |
| | 24 | | | | 180. | |
| RECOVERY | 1 | 142 | 145 | 135 | 139 | 139 |
| | 2 | 120 | 124 | 115 | 122 | 125 |
| | 3 | 112 | 115 | 109 | 114 | 119 |
| | 4 | 110 | 113 | 108 | 110 | 114 |
| | 5 | 110 | 110 | 111 | 108 | 112 |

TABLE XXV

MEAN HEART RATES TREADMILL RUN TO EXHAUSTION

FIRST TEST PERIOD

| GROUP | | A | $A_1$ | $A_2$ | B | C |
|---|---|---|---|---|---|---|
| REST | | 81 | 83 | 79 | 82 | 92 |
| | MINS. | | | | | |
| EXERCISE | 0.5 | 155 | 160 | 156 | 162 | 162 |
| | 1.0 | 167 | 172 | 165 | 171 | 173 |
| | 1.5 | 178 | 182 | 173 | 175 | 178 |
| | 2.0 | 183 | 187 | 180 | 179 | 180 |
| | 2.5 | 184 | 186 | 182 | 182 | 185 |
| | 3.0 | 182 | | 182 | 183 | 186 |
| | 3.5 | 188 | | 188 | 182 | 188 |
| | 4.0 | 188 | | 188 | 180 | 188 |
| | 4.5 | | | | 180 | 188 |
| | 5.0 | | | | | 188 |
| BEST RUN | | 4:00 | 2:58 | 4:00 | 4:30 | 5:08 |
| RECOVERY | 1 | 158 | 161 | 158 | 156 | 156 |
| | 2 | 137 | 142 | 137 | 135 | 135 |
| | 3 | 127 | 133 | 127 | 127 | 126 |
| | 4 | 121 | 123 | 121 | 121 | 121 |
| | 5 | 121 | 123 | 121 | 120 | 122 |

TABLE XXVI

MEAN HEART RATES TREADMILL RUN TO EXHAUSTION

SECOND TEST PERIOD

| GROUP | | A | $A_1$ | $A_2$ | B | C |
|---|---|---|---|---|---|---|
| REST | | 73 | 75 | 71 | 76 | 89 |
| | MINS. | | | | | |
| EXERCISE | 0.5 | 160 | 162 | 158 | 163 | 164 |
| | 1.0 | 166 | 169 | 164 | 167 | 173 |
| | 1.5 | 173 | 177 | 169 | 173 | 179 |
| | 2.0 | 176 | 180 | 172 | 175 | 182 |
| | 2.5 | 180 | 182 | 177 | 178 | 185 |
| | 3.0 | 180 | 182 | 177 | 180 | 186 |
| | 3.5 | 182 | 188 | 177 | 181 | 188 |
| | 4.0 | 180 | | 180 | 175 | 196 |
| | 4.5 | | | | 178 | |
| | 5.0 | | | | 173 | |
| | 5.5 | | | | 173 | |
| | 6.0 | | | | 173 | |
| BEST RUN | | 4:22 | 3:57 | 4:22 | 6:17 | 4:15 |
| RECOVERY | 1 | 156 | 158 | 153 | 153 | 157 |
| | 2 | 136 | 142 | 130 | 133 | 136 |
| | 3 | 126 | 133 | 119 | 126 | 128 |
| | 4 | 121 | 126 | 117 | 118 | 121 |
| | 5 | 119 | 125 | 114 | 119 | 122 |

TABLE XXVII

MEAN HEART RATES TREADMILL RUN TO EXHAUSTION

THIRD TEST PERIOD

| GROUP | MINS. | A | $A_1$ | $A_2$ | B | C |
|---|---|---|---|---|---|---|
| REST | | 72 | 74 | 71 | 75 | 86 |
| EXERCISE | 0.5 | 161 | 164 | 158 | 163 | 163 |
| | 1.0 | 171 | 173 | 169 | 171 | 174 |
| | 1.5 | 175 | 179 | 172 | 176 | 179 |
| | 2.0 | 180 | 182 | 178 | 178 | 183 |
| | 2.5 | 179 | 180 | 179 | 180 | 185 |
| | 3.0 | 181 | 183 | 179 | 181 | 185 |
| | 3.5 | 182 | 184 | 180 | 182 | 188 |
| | 4.0 | 182 | | 182 | 176 | 188 |
| | 4.5 | 185 | | 185 | 178 | |
| | 5.0 | 188 | | 188 | 181 | |
| | 5.5 | | | | 173 | |
| | 6.0 | | | | 173 | |
| | 6.5 | | | | 173 | |
| | 7.0 | | | | 173 | |
| BEST RUN | | 5:27 | 3:52 | 5:27 | 7:07 | 4:28 |
| RECOVERY | 1 | 158 | 162 | 154 | 154 | 159 |
| | 2 | 136 | 144 | 128 | 135 | 139 |
| | 3 | 126 | 132 | 121 | 126 | 129 |
| | 4 | 122 | 129 | 116 | 122 | 127 |
| | 5 | 122 | 128 | 116 | 122 | 124 |

TABLE XXVIII

MEAN VALUES FOR $O_2$ CONSUMPTION (c.c./Kg. Body Wt./Min.) BALKE-WARE TREADMILL TEST

| GROUP | | A | | $A_1$ | | $A_2$ | | B | | C | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TEST PERIOD | | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 3 |
| REST | | 5.9 | 5.9 | 5.7 | 6.2 | 6.1 | 5.5 | 6.0 | 6.0 | 6.3 | 6.3 |
| | INTERVAL | | | | | | | | | | |
| EXERCISE | 1 Min. | 19.5 | 19.3 | 19.2 | 19.1 | 19.7 | 19.4 | 19.9 | 18.3 | 17.8 | 18.6 |
| | 5 Min. | 23.3 | 24.8 | 23.0 | 23.2 | 23.6 | 26.3 | 22.4 | 24.2 | 23.3 | 23.7 |
| | 10 Min. | 33.2 | 33.8 | 34.6 | 32.9 | 31.8 | 34.7 | 30.2 | 32.3 | 30.0 | 33.1 |
| | Pulse 165 | 42.9 | 41.3 | 42.4 | 40.8 | 43.4 | 41.8 | 41.6 | 44.6 | 42.1 | 41.2 |
| | Pulse 175 | 43.9 | 44.9 | 43.2 | 44.1 | 44.5 | 45.8 | 41.3 | 46.2 | 44.9 | 44.1 |
| | Pulse 180 | 45.6 | 44.6 | 44.0 | 45.6 | 47.1 | 43.6 | 45.3 | 51.9 | 46.9 | 44.9 |
| RECOVERY | 1 Min. | 16.0 | 15.3 | 15.8 | 15.6 | 16.3 | 14.9 | 14.4 | 14.4 | 15.3 | 13.6 |
| | 5 Min. | 6.9 | 6.8 | 6.8 | 6.5 | 6.9 | 7.0 | 6.6 | 6.5 | 7.5 | 8.0 |

TABLE XXIX

MEAN VALUES FOR $O_2$ CONSUMPTION (c.c./Kg. Body Wt./Min.) TREADMILL RUN TO EXHAUSTION

| GROUP | | A | | $A_1$ | | $A_2$ | | B | | C | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TEST PERIOD | | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 3 |
| REST | | 7.3 | 5.9 | 7.7 | 6.2 | 6.9 | 5.5 | 7.2 | 5.8 | 7.7 | 5.8 |
| | INTERVAL | | | | | | | | | | |
| EXERCISE | 1 Min. | 51.2 | 50.6 | 49.5 | 49.3 | 53.3 | 54.0 | 52.2 | 51.2 | 51.2 | 52.1 |
| | 2 Min. | 51.4 | 57.8 | 37.1 | 56.7 | 58.6 | 58.7 | 59.7 | 58.8 | 52.8 | 57.4 |
| | 3 Min. | 61.6 | 61.9 | -- | -- | 61.6 | 61.9 | 67.2 | 60.0 | 52.8 | 56.6 |
| | Peak | 55.3 | 57.0 | 50.7 | 56.0 | 60.0 | 58.0 | 60.9 | 57.7 | 56.2 | 54.1 |
| RECOVERY | 1 Min. | 22.7 | 22.4 | 21.4 | 23.8 | 24.1 | 20.6 | 23.1 | 20.2 | 23.0 | 20.7 |
| | 5 Min. | 11.9 | 12.3 | 11.6 | 14.0 | 12.1 | 10.6 | 12.6 | 10.8 | 11.2 | 10.7 |

TABLE XXX

MEAN RESPIRATORY QUOTIENTS BALKE-WARE TREADMILL TEST

| GROUP / TEST PERIOD | | A 1 | A 3 | $A_1$ 1 | $A_1$ 3 | $A_2$ 1 | $A_2$ 3 | B 1 | B 3 | C 1 | C 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| REST | | .757 | .822 | .726 | .770 | .788 | .874 | .790 | .780 | .846 | .869 |
| | INTERVAL | | | | | | | | | | |
| EXERCISE | 1 Min. | .745 | .772 | .768 | .780 | .724 | .764 | .750 | .754 | .738 | .772 |
| | 5 Min. | .789 | .834 | .786 | .860 | .792 | .808 | .803 | .800 | .814 | .844 |
| | 10 Min. | .852 | .908 | .842 | .892 | .862 | .924 | .861 | .879 | .869 | .866 |
| | Pulse 165 | .900 | .922 | .925 | .910 | .875 | .934 | .906 | .902 | .894 | .891 |
| | Pulse 175 | .926 | .924 | .958 | .910 | .894 | .938 | .923 | .937 | .929 | .927 |
| | Pulse 180 | .932 | 1.016 | .960 | .986 | .904 | 1.046 | .932 | .983 | .949 | .972 |
| RECOVERY | 1 Min. | 1.126 | 1.229 | 1.172 | 1.270 | 1.080 | 1.326 | 1.158 | 1.218 | 1.164 | 1.214 |
| | 5 Min. | .810 | .966 | .836 | .950 | .784 | .918 | .869 | 1.011 | .891 | 1.010 |

TABLE XXXI

MEAN RESPIRATORY QUOTIENTS TREADMILL RUN TO EXHAUSTION

| GROUP<br>TEST PERIOD | | A<br>1 | <br>3 | $A_1$<br>1 | <br>3 | $A_2$<br>1 | <br>3 | B<br>1 | <br>3 | C<br>1 | <br>3 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| REST | | .814 | .778 | .806 | .800 | .822 | .756 | .770 | .780 | .866 | .858 |
| | INTERVAL | | | | | | | | | | |
| EXERCISE | 1 Min. | 1.053 | .967 | 1.028 | 1.006 | .978 | .928 | .963 | 1.019 | .970 | 1.002 |
| | 2 Min. | 1.192 | 1.126 | 1.200 | 1.148 | 1.185 | 1.104 | 1.145 | 1.141 | 1.167 | 1.108 |
| | 3 Min. | 1.170 | 1.027 | -- | -- | 1.170 | 1.027 | 1.110 | 1.118 | 1.187 | 1.095 |
| | Peak | 1.201 | 1.137 | 1.240 | 1.186 | 1.162 | 1.088 | 1.107 | 1.103 | 1.170 | 1.244 |
| RECOVERY | 1 Min. | 1.499 | 1.484 | 1.582 | 1.556 | 1.416 | 1.412 | 1.415 | 1.419 | 1.396 | 1.505 |
| | 5 Min. | 1.160 | 1.115 | 1.064 | 1.070 | 1.128 | 1.102 | .980 | 1.110 | 1.072 | 1.221 |

TABLE XXXII

MEAN VALUES FOR $CO_2$ ELIMINATION (LITERS/MIN.) BALKE-WARE TREADMILL TEST

| GROUP | | A | | $A_1$ | | $A_2$ | | B | | C | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TEST PERIOD | | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 3 |
| REST | | .331 | .356 | .316 | .371 | .347 | .341 | .339 | .340 | .386 | .356 |
| | INTERVAL | | | | | | | | | | |
| EXERCISE | 1 Min. | 1.07 | 1.08 | 1.12 | 1.14 | 1.03 | 1.03 | 1.06 | .959 | .948 | 1.00 |
| | 5 Min. | 1.38 | 1.52 | 1.42 | 1.54 | 1.34 | 1.51 | 1.28 | 1.35 | 1.34 | 1.40 |
| | 10 Min. | 2.02 | 2.26 | 2.26 | 2.26 | 1.77 | 2.27 | 1.99 | 1.99 | 1.84 | 2.02 |
| | Pulse 165 | 2.86 | 2.82 | 2.96 | 2.85 | 2.76 | 2.79 | 2.73 | 2.85 | 2.65 | 2.58 |
| | Pulse 175 | 3.03 | 3.09 | 3.18 | 3.11 | 2.88 | 3.07 | 2.72 | 3.06 | 2.93 | 2.94 |
| | Pulse 180 | 3.17 | 3.34 | 3.25 | 3.43 | 3.08 | 3.25 | 3.04 | 3.32 | 3.15 | 3.08 |
| RECOVERY | 1 Min. | 1.35 | 1.42 | 1.41 | 1.52 | 1.28 | 1.32 | 1.18 | 1.25 | 1.27 | 1.17 |
| | 5 Min. | .417 | .452 | .443 | .472 | .391 | .432 | .407 | .465 | .466 | .484 |

TABLE XXXIII

MEAN VALUES FOR $CO_2$ ELIMINATION (LITERS/MIN.) TREADMILL RUN TO EXHAUSTION

| GROUP | | A | | $A_1$ | | $A_2$ | | B | | C | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TEST PERIOD | | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 3 |
| REST | | .448 | .344 | .482 | .393 | .414 | .294 | .398 | .323 | .482 | .348 |
| | INTERVAL | | | | | | | | | | |
| EXERCISE | 1 Min. | 3.86 | 3.81 | 3.96 | 3.83 | 3.76 | 3.59 | 3.56 | 3.70 | 3.48 | 3.68 |
| | 2 Min. | 4.35 | 4.75 | 3.23 | 4.87 | 5.00 | 4.62 | 4.87 | 4.76 | 4.43 | 4.44 |
| | 3 Min. | 5.97 | 4.47 | -- | -- | 5.97 | 4.47 | 5.33 | 4.86 | 4.19 | 4.52 |
| | Peak | 4.90 | 4.82 | 4.87 | 5.13 | 4.92 | 4.50 | 4.80 | 4.52 | 4.60 | 4.55 |
| RECOVERY | 1 Min. | 2.56 | 2.46 | 2.65 | 2.79 | 2.47 | 2.13 | 2.31 | 2.04 | 2.27 | 2.12 |
| | 5 Min. | .974 | .838 | .976 | 1.04 | .972 | .642 | .874 | .854 | .843 | .953 |

TABLE XXXIV

MEAN VALUES FOR VOLUMES OF INSPIRED AIR (LITERS/MIN., STPD.) BALKE-WARE TREADMILL TEST

| GROUP<br>TEST PERIOD | | A<br>1 | 3 | $A_1$<br>1 | 3 | $A_2$<br>1 | 3 | B<br>1 | 3 | C<br>1 | 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| REST | | 12.4 | 12.0 | 12.4 | 12.2 | 12.3 | 11.8 | 11.2 | 10.8 | 12.2 | 12.3 |
| | INTERVAL | | | | | | | | | | |
| EXERCISE | 1 Min. | 26.1 | 26.1 | 26.1 | 26.7 | 26.1 | 25.4 | 25.2 | 22.0 | 22.7 | 22.2 |
| | 5 Min. | 31.1 | 33.3 | 31.2 | 33.9 | 31.9 | 32.7 | 26.8 | 27.9 | 27.5 | 27.9 |
| | 10 Min. | 44.3 | 46.0 | 45.7 | 45.5 | 46.2 | 46.4 | 36.9 | 38.6 | 38.6 | 39.0 |
| | Pulse 165 | 58.6 | 58.2 | 55.7 | 56.0 | 59.9 | 60.2 | 50.9 | 54.0 | 50.0 | 50.3 |
| | Pulse 175 | 63.7 | 65.1 | 63.0 | 63.4 | 66.5 | 66.7 | 51.6 | 62.9 | 56.4 | 59.2 |
| | Pulse 180 | 68.1 | 72.3 | 73.0 | 73.1 | 70.6 | 70.4 | 58.8 | 72.5 | 63.7 | 60.9 |
| RECOVERY | 1 Min. | 37.3 | 36.5 | 38.1 | 37.8 | 35.5 | 35.2 | 29.6 | 28.4 | 32.7 | 27.8 |
| | 5 Min. | 16.9 | 16.0 | 16.2 | 16.2 | 15.7 | 15.7 | 13.5 | 14.6 | 15.2 | 13.5 |

TABLE XXXV

MEAN VALUES FOR VOLUMES OF INSPIRED AIR (LITERS/MIN., STPD.) TREADMILL RUN TO EXHAUSTION

| GROUP | | A | | $A_1$ | | $A_2$ | | B | | C | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TEST PERIOD | | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 3 |
| REST | | 14.8 | 12.6 | 15.4 | 13.8 | 14.2 | 11.4 | 12.6 | 11.0 | 13.7 | 11.4 |
| | INTERVAL | | | | | | | | | | |
| EXERCISE | 1 Min. | 74.7 | 75.7 | 75.6 | 75.3 | 73.7 | 75.1 | 67.9 | 74.0 | 67.4 | 72.4 |
| | 2 Min. | 77.3 | 97.5 | 57.7 | 97.7 | 97.5 | 97.4 | 91.1 | 99.6 | 82.8 | 90.7 |
| | 3 Min. | 110.7 | 95.9 | -- | -- | 110.7 | 95.9 | 106.6 | 100.4 | 73.3 | 88.3 |
| | Peak | 101.5 | 105.1 | 99.8 | 109.0 | 102.9 | 101.2 | 98.2 | 98.9 | 93.4 | 96.8 |
| RECOVERY | 1 Min. | 69.4 | 65.0 | 68.9 | 77.3 | 69.8 | 62.2 | 60.2 | 54.2 | 57.5 | 55.7 |
| | 5 Min. | 35.3 | 34.1 | 34.2 | 36.8 | 36.8 | 31.3 | 29.1 | 27.7 | 26.8 | 29.0 |

TABLE XXXVI

MEAN VALUES FOR EXPIRED AIR VOLUMES (LITERS/MIN., STPD.) BALKE-WARE TREADMILL TEST

| GROUP / TEST PERIOD | INTERVAL | A 1 | A 3 | $A_1$ 1 | $A_1$ 3 | $A_2$ 1 | $A_2$ 3 | B 1 | B 3 | C 1 | C 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| REST | | 12.3 | 11.9 | 12.3 | 12.1 | 12.2 | 11.7 | 11.4 | 9.8 | 12.1 | 12.2 |
| EXERCISE | 1 Min. | 25.8 | 25.7 | 25.8 | 26.4 | 25.7 | 25.0 | 23.9 | 21.7 | 22.4 | 21.9 |
| | 5 Min. | 30.8 | 32.9 | 30.9 | 33.8 | 30.6 | 31.9 | 25.6 | 27.5 | 27.1 | 27.6 |
| | 10 Min. | 43.9 | 45.7 | 45.1 | 45.2 | 42.6 | 46.2 | 36.5 | 38.3 | 34.3 | 38.6 |
| | Pulse 165 | 58.3 | 57.8 | 58.6 | 55.7 | 57.9 | 59.9 | 50.6 | 53.6 | 49.7 | 50.0 |
| | Pulse 175 | 63.0 | 64.8 | 65.8 | 63.0 | 60.1 | 66.5 | 51.3 | 62.6 | 56.2 | 59.0 |
| | Pulse 180 | 67.9 | 71.8 | 69.1 | 73.0 | 66.6 | 70.6 | 57.1 | 72.5 | 63.5 | 60.8 |
| RECOVERY | 1 Min. | 38.5 | 36.8 | 40.0 | 38.1 | 36.9 | 35.5 | 30.4 | 28.5 | 32.9 | 28.0 |
| | 5 Min. | 16.8 | 16.0 | 17.4 | 16.2 | 16.2 | 15.7 | 13.4 | 14.6 | 15.1 | 13.5 |

TABLE XXXVII

MEAN VALUES FOR EXPIRED AIR VOLUMES (LITERS/MIN., STPD.) TREADMILL RUN TO EXHAUSTION

| GROUP | | A | | $A_1$ | | $A_2$ | | B | | C | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TEST PERIOD | | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 3 |
| REST | | 14.5 | 12.5 | 15.3 | 13.7 | 13.7 | 11.4 | 10.9 | 7.8 | 13.3 | 11.4 |
| | INTERVAL | | | | | | | | | | |
| EXERCISE | 1 Min. | 74.7 | 75.5 | 75.8 | 75.4 | 73.6 | 75.6 | 67.9 | 74.0 | 67.3 | 72.4 |
| | 2 Min. | 78.3 | 98.1 | 58.2 | 98.3 | 98.3 | 92.8 | 91.7 | 100.2 | 83.4 | 91.2 |
| | 3 Min. | 111.6 | 96.0 | -- | -- | 111.6 | 96.0 | 107.1 | 101.0 | 74.0 | 88.7 |
| | Peak | 103.6 | 105.7 | 100.7 | 109.8 | 106.4 | 101.5 | 98.7 | 99.3 | 94.1 | 97.5 |
| RECOVERY | 1 Min. | 70.2 | 65.5 | 69.9 | 78.2 | 70.5 | 62.8 | 61.0 | 54.8 | 58.2 | 56.4 |
| | 5 Min. | 35.6 | 33.9 | 34.2 | 41.1 | 36.9 | 31.4 | 29.1 | 27.8 | 26.9 | 29.1 |

TABLE XXXVIII

SUMMARY SHEET

RELATIVE GAINS AND LOSSES CONCERNED WITH TREADMILL PERFORMANCE AND ASSOCIATED CARDIO-RESPIRATORY VARIABLES FOLLOWING 5 WEEKS OF TRAINING

| VARIABLE TESTED | GROUP | BALKE-WARE | | | EXHAUSTION RUN | | |
|---|---|---|---|---|---|---|---|
| | | REST | EXERCISE | RECOVERY | REST | EXERCISE | RECOVERY |
| HEART RATE BTS/MIN. | A | -2 | +(2-5) | -(1-4) | -9*** | -(2-3) | 0 |
| | B | -5 | 0 | -(1-2) | -7 | -(1-2) | 0 |
| | C | -7 | +(2-5) | 0 | -6 | +(1-3) | +(2-6) |
| | $A_1$ | +2 | +(1-5) | -(2-5) | -9* | -(2-5) | +(1-5) |
| | $A_2$ | -5 | 0 | -(2-4) | -8 | -(2-6) | -(2-4) |
| $O_2$ CONS. cc/Kg/ Min. | A | 0 | 0 | 0 | - | + | 0 |
| | B | 0 | + | 0 | - | - | - |
| | C | 0 | 0 | 0 | - | + | - |
| | $A_1$ | 0 | 0 | 0 | - | + | + |
| | $A_2$ | 0 | 0 | - | - | 0 | - |
| $CO_2$ ELIM. L/Min. | A | 0 | 0 | 0 | - | - | - |
| | B | 0 | + | + | 0 | - | 0 |
| | C | 0 | 0 | 0 | - | 0 | + |
| | $A_1$ | 0 | 0 | 0 | - | 0 | 0 |
| | $A_2$ | 0 | 0 | + | - | - | - |
| R.Q. | A | + | + | + | - | - | - |
| | B | 0 | 0 | + | 0 | 0 | 0 |
| | C | + | 0 | + | - | + | + |
| | $A_1$ | + | 0 | + | - | - | - |
| | $A_2$ | + | + | + | - | - | - |
| TREAD-MILL PERFORM. | A | +0.9 | | | +0.92*** | | |
| | B | +1.6* | | | +1.02** | | |
| | C | -0.6 | | | +0.1 | | |
| | $A_1$ | +0.1 | | | +0.71* | | |
| | $A_2$ | +1.7* | | | +1.14* | | |

*** Sig. at .01 Level
** Sig. at .02 Level
* Sig. at .05 Level

+ Denotes a Gain or Higher Value
- Denotes a Loss or Lower Value
0 Denotes Little or No Change

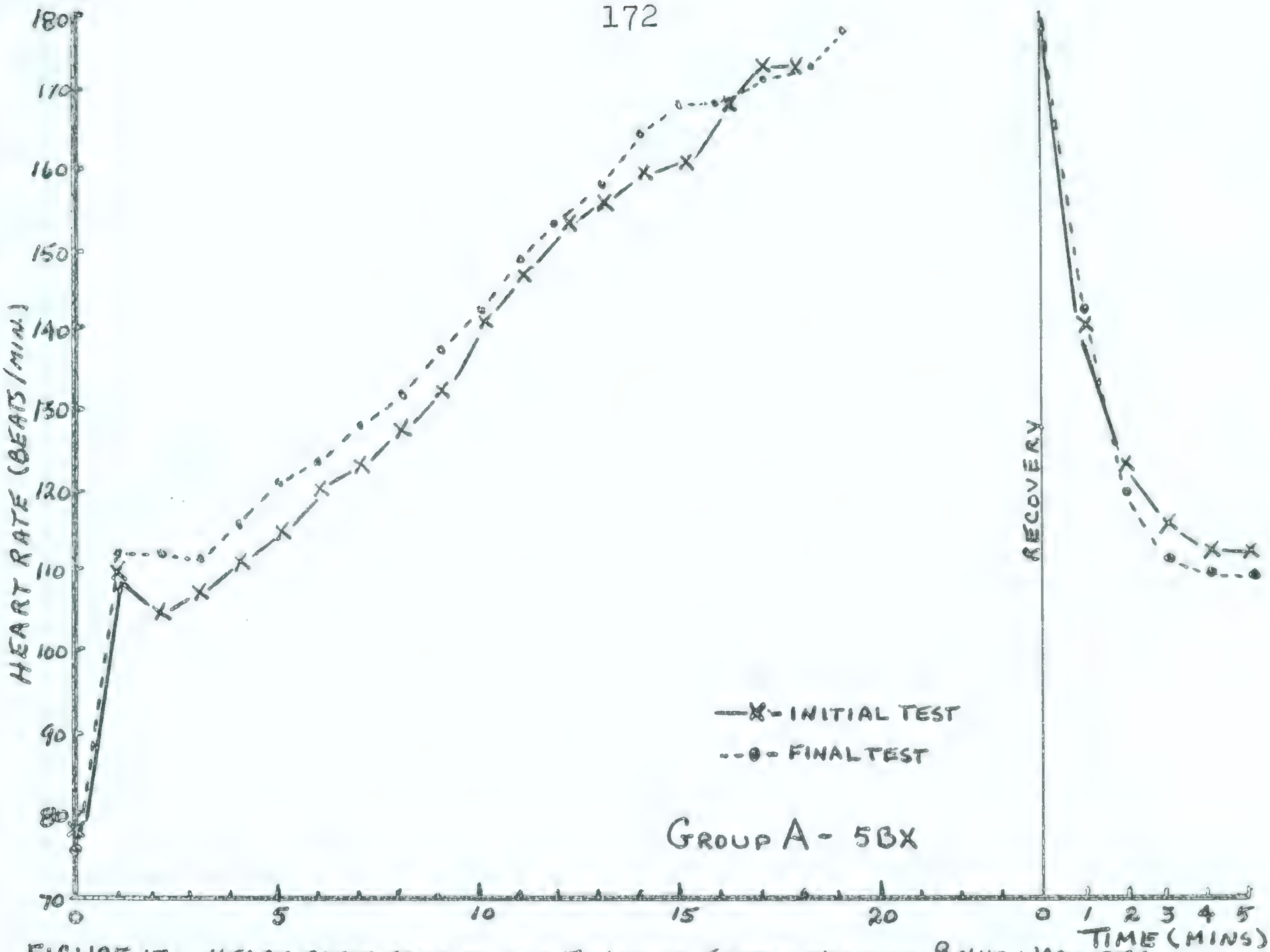



FIGURE 17. HEART RATES PRIOR TO AND FOLLOWING 5 WEEKS TRAINING. BALKE-WARE TEST.

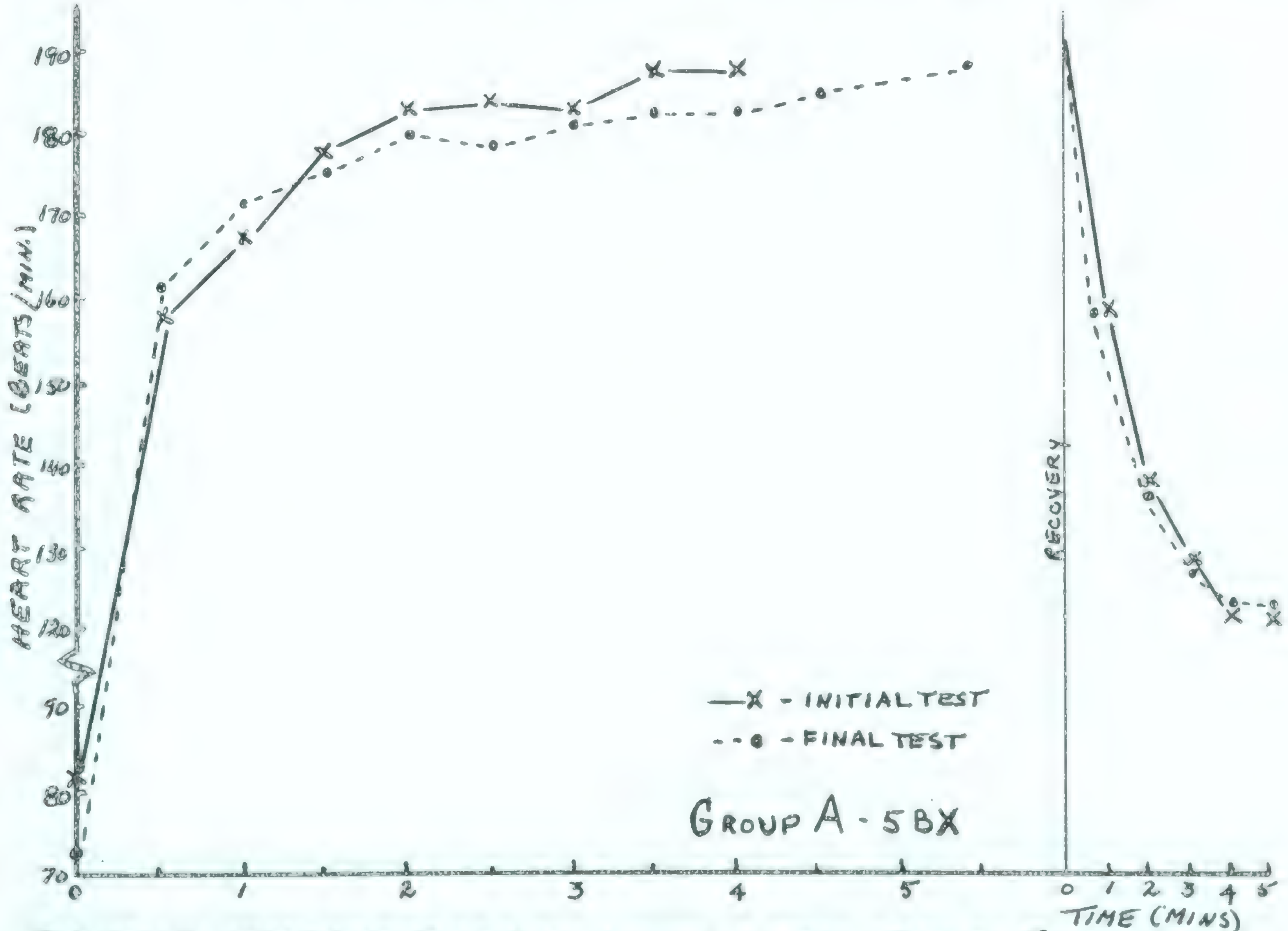



FIGURE 18. HEART RATES PRIOR TO AND FOLLOWING 5 WEEKS TRAINING. EXHAUSTION RUN.

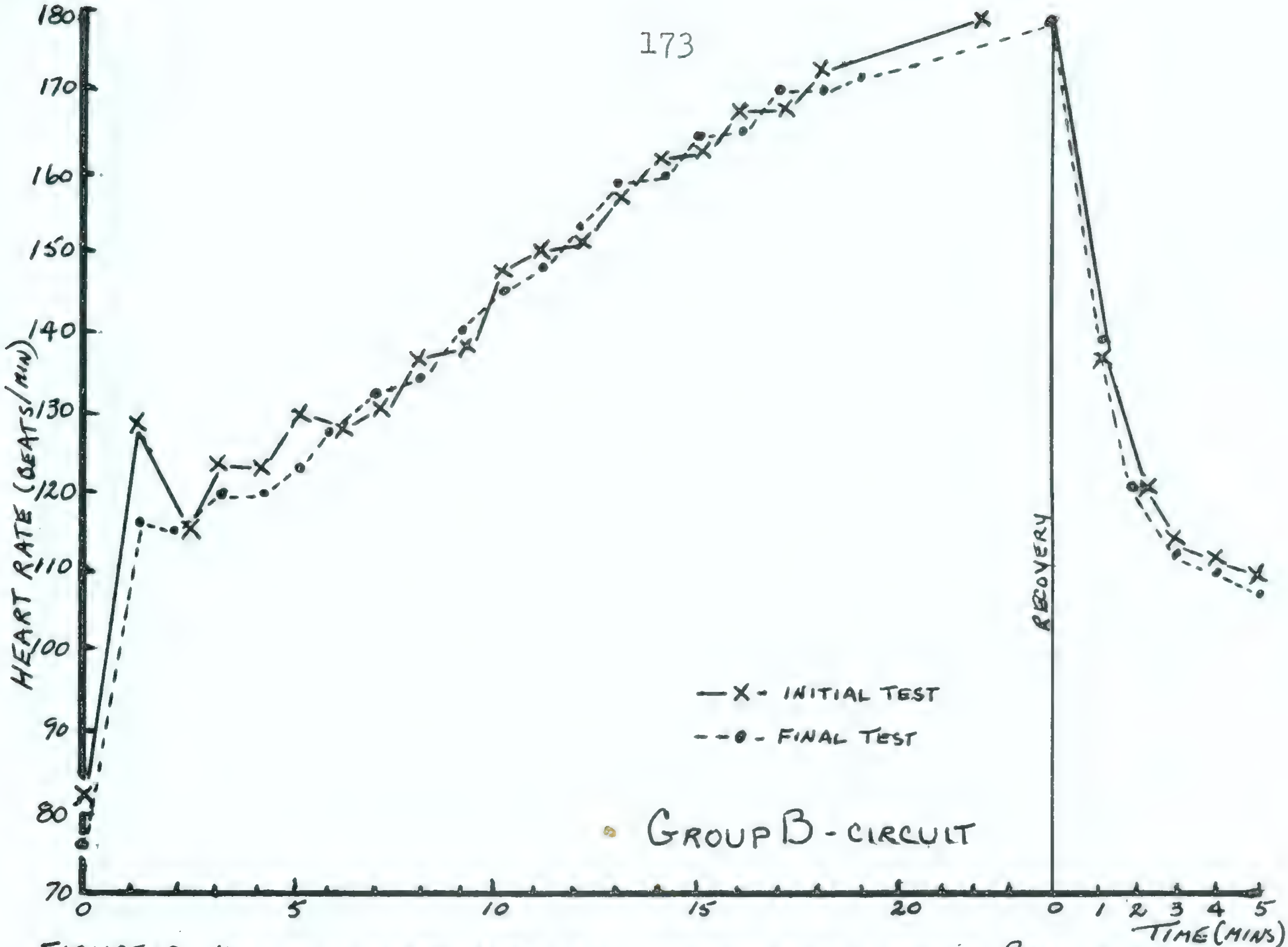



FIGURE 19. MEAN HEART RATES PRIOR TO AND FOLLOWING 5 WEEKS TRAINING. BALKE-WARE TEST.

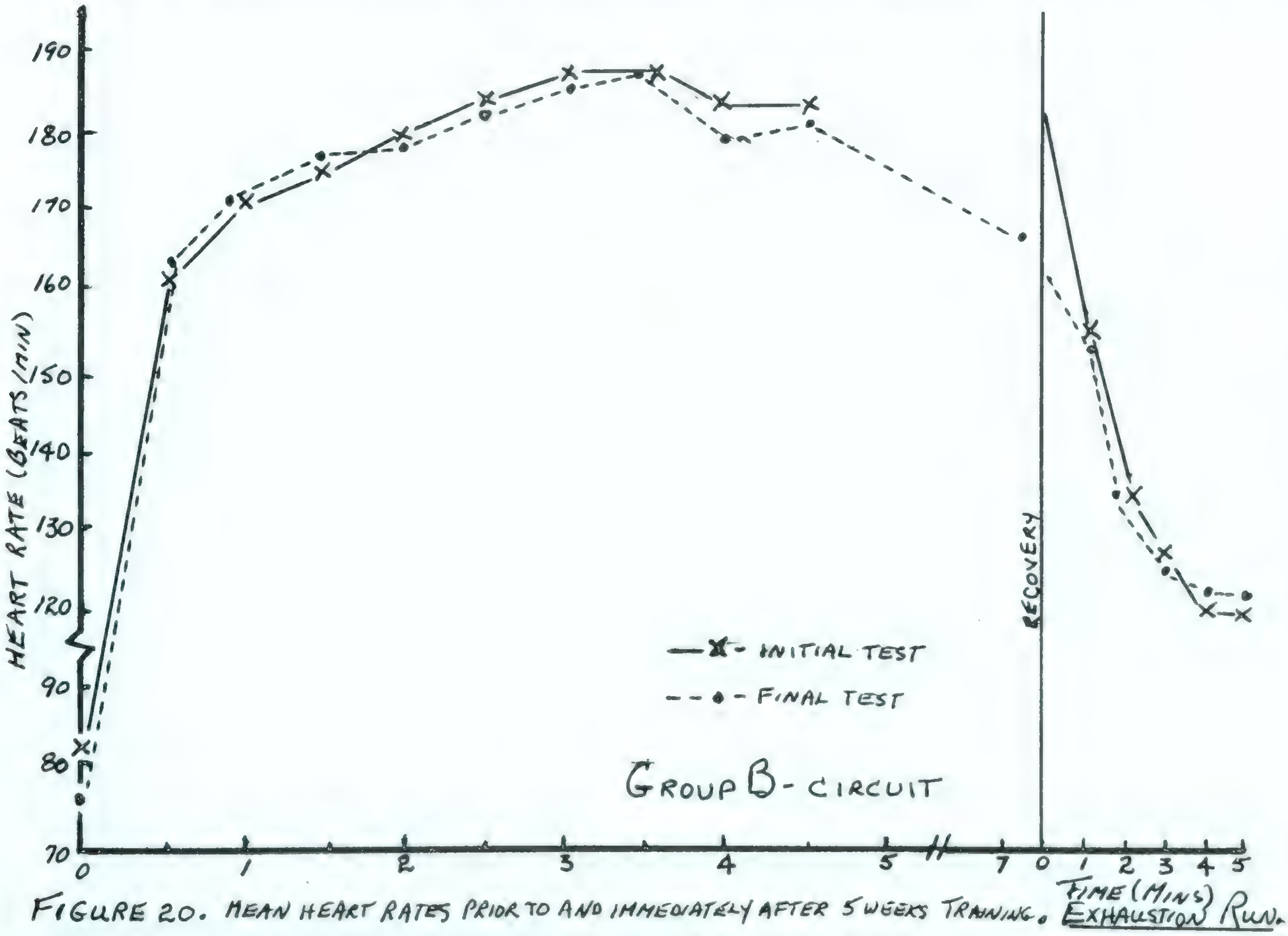
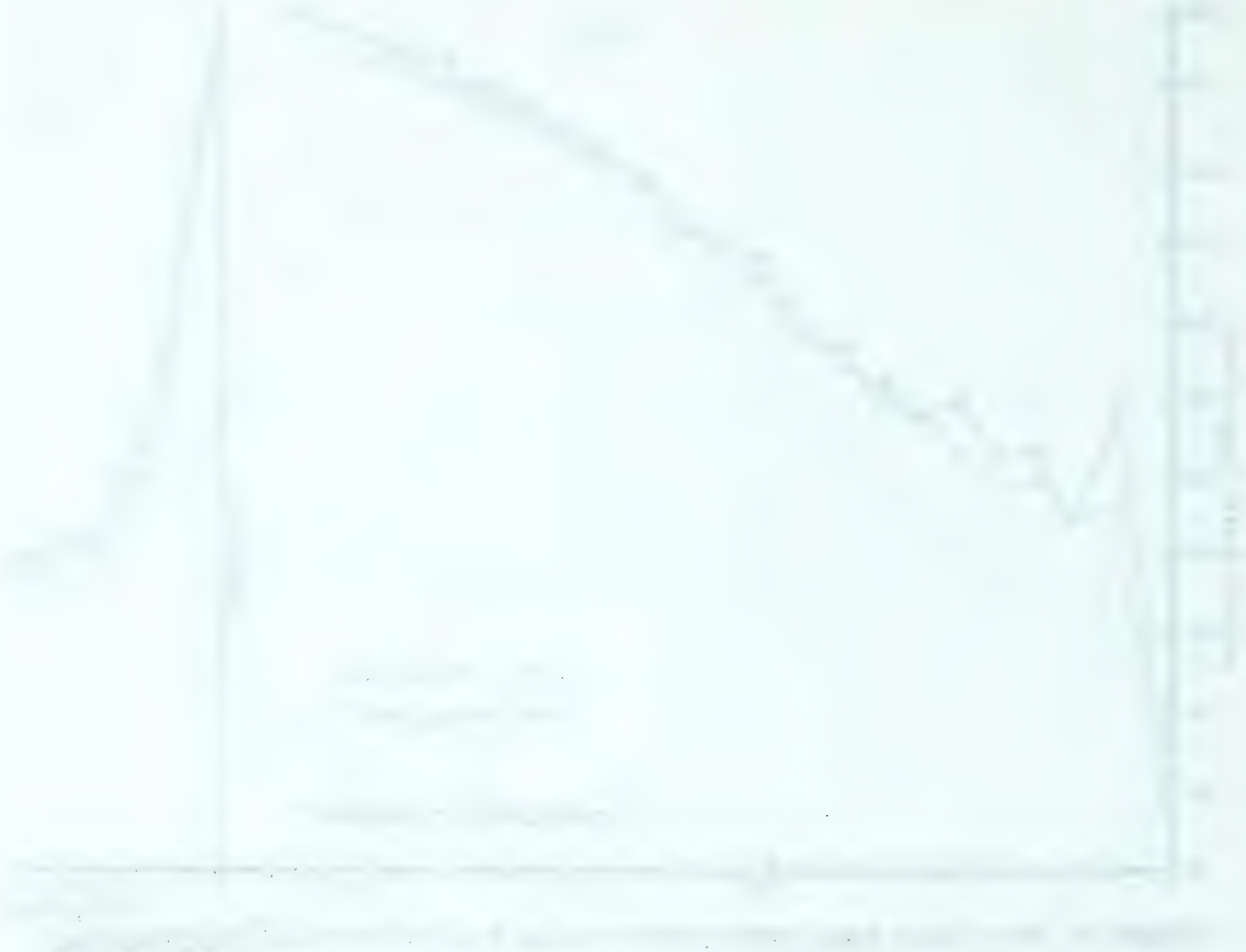



FIGURE 20. MEAN HEART RATES PRIOR TO AND IMMEDIATELY AFTER 5 WEEKS TRAINING. EXHAUSTION RUN.



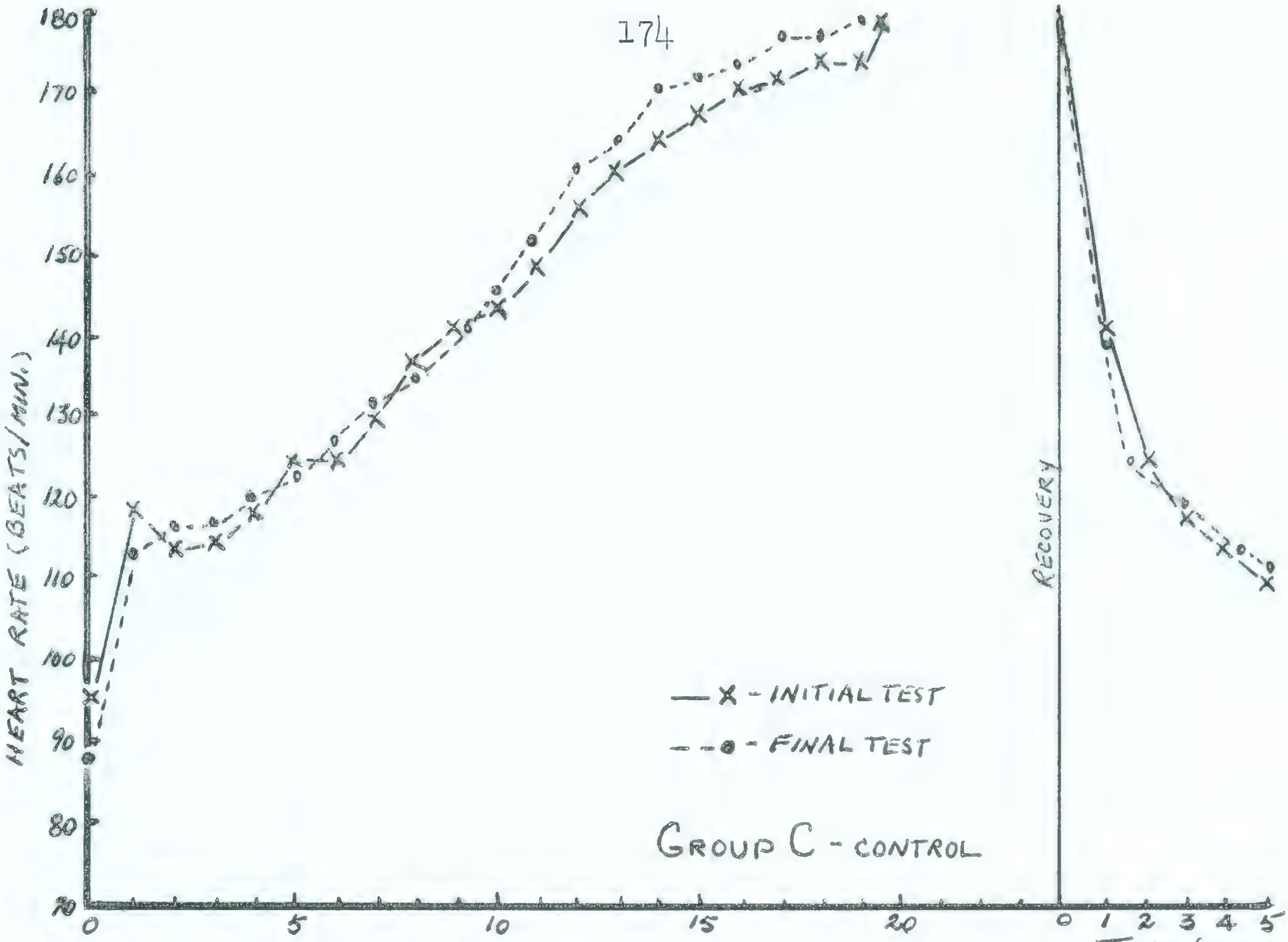



FIGURE 21. MEAN HEART RATES PRIOR TO AND FOLLOWING 5 WEEKS INACTIVITY. BALKE-WARE TEST.

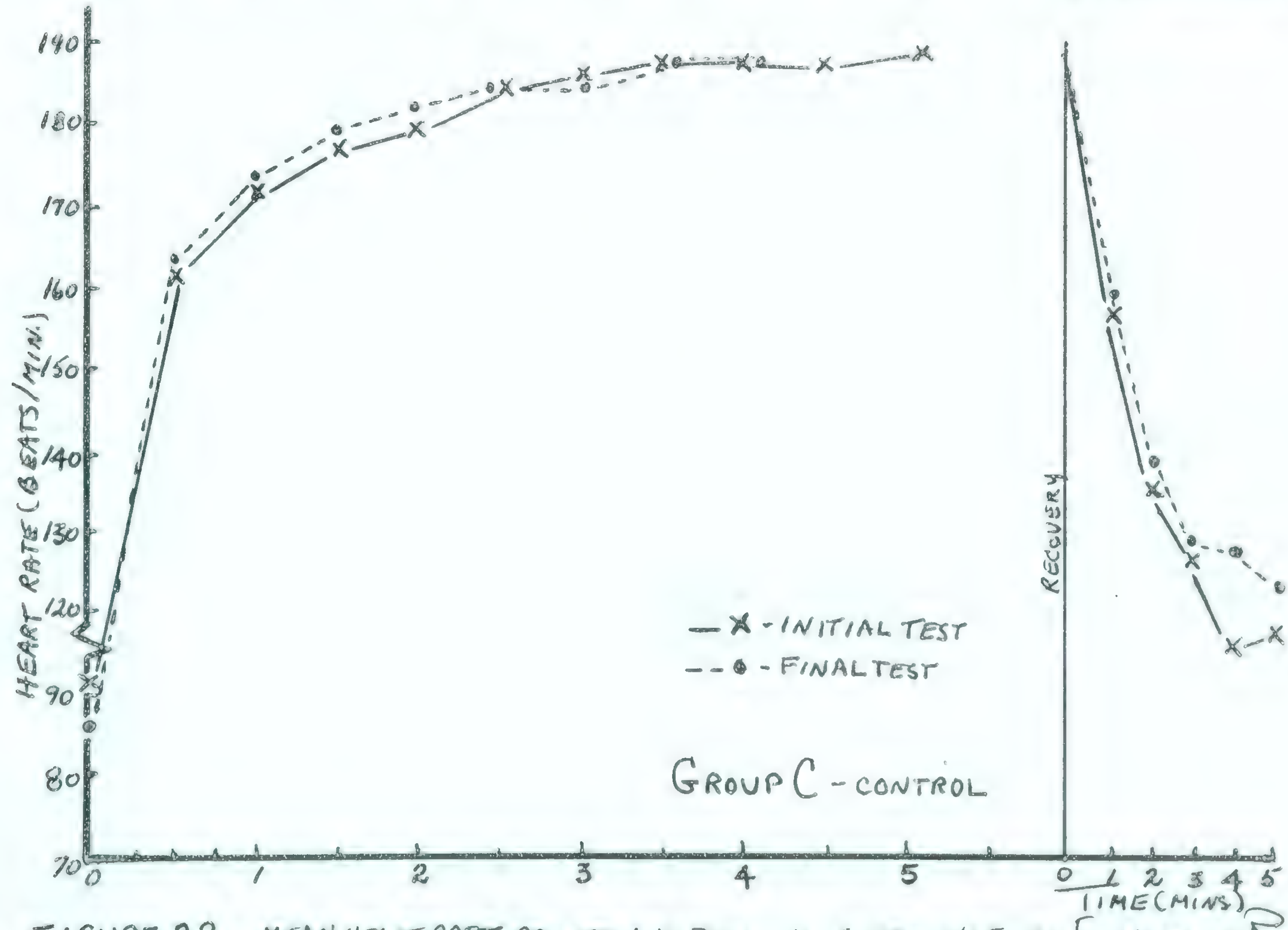



FIGURE 22. MEAN HEART RATES PRIOR TO AND FOLLOWING 5 WEEKS INACTIVITY. EXHAUSTION RUN.

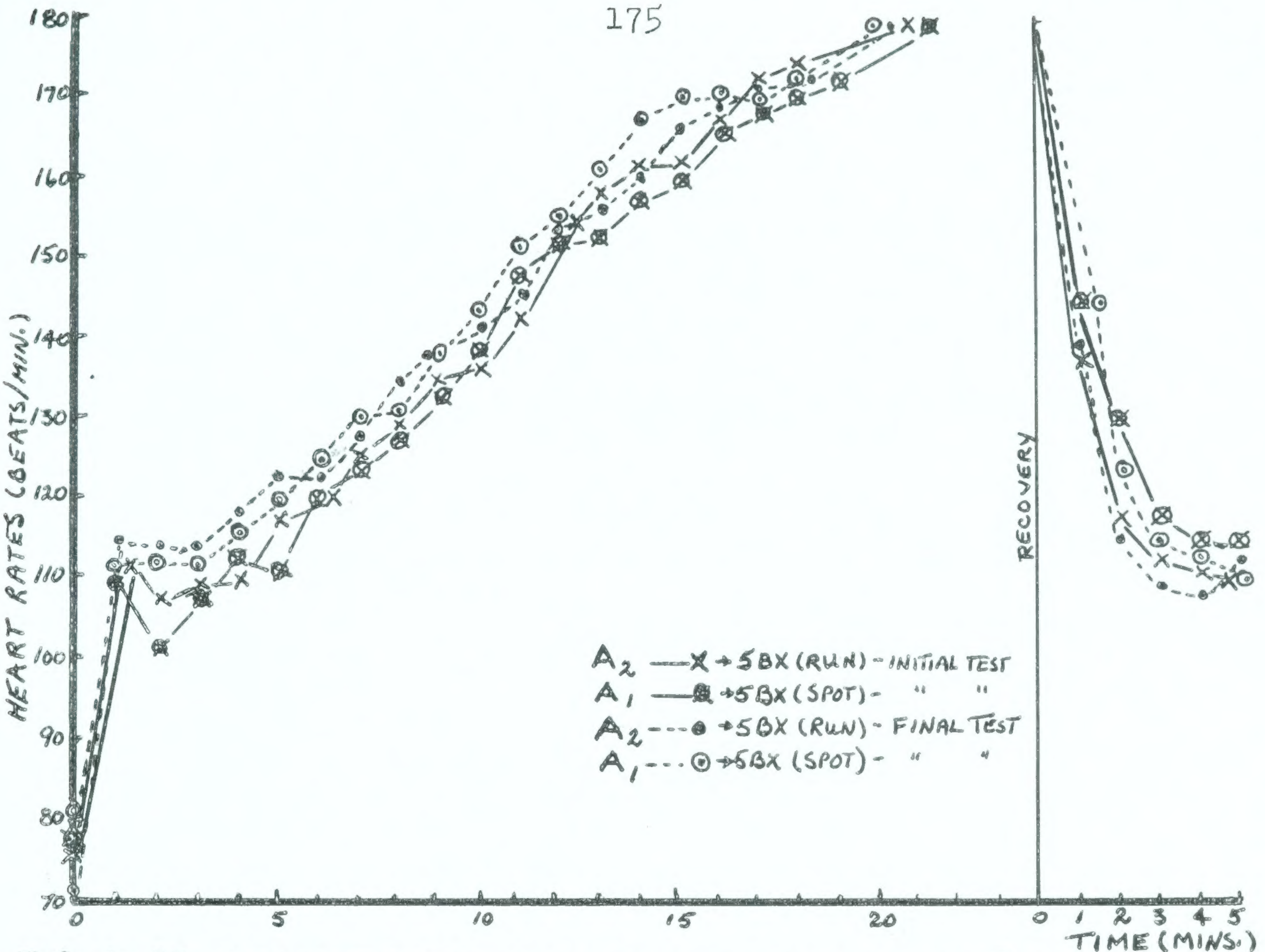



FIGURE 23. MEAN HEART RATES PRIOR TO AND FOLLOWING 5 WEEKS TRAINING. BALKE-WARE TEST.

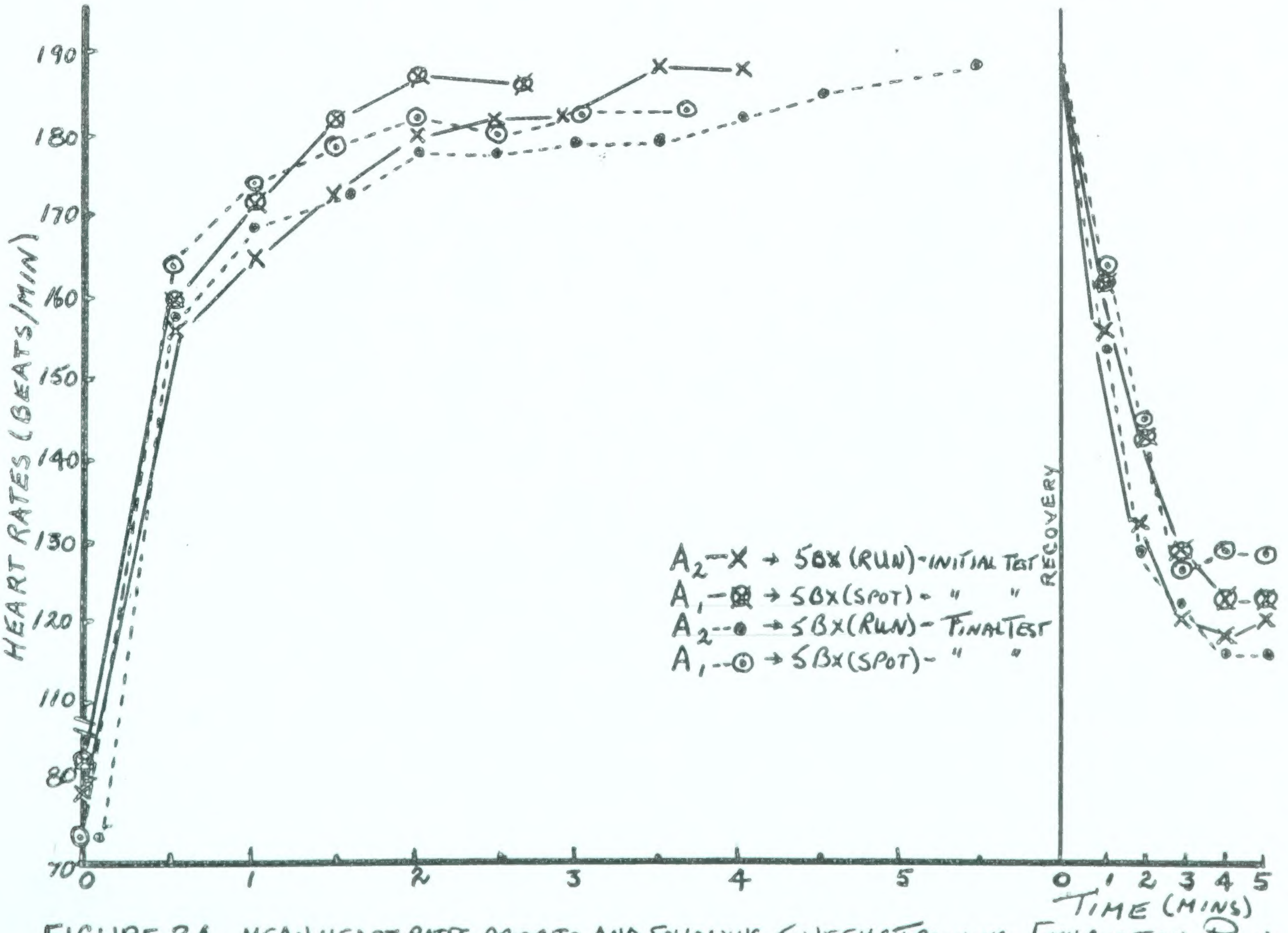



FIGURE 24. MEAN HEART RATES PRIOR TO AND FOLLOWING 5 WEEKS TRAINING. EXHAUSTION RUN.

FIGURE 23. MEAN HEART RATES PRIOR TO AND FOLLOWING 5 WEEKS TRAINING - DISTANCE-RACE TEST